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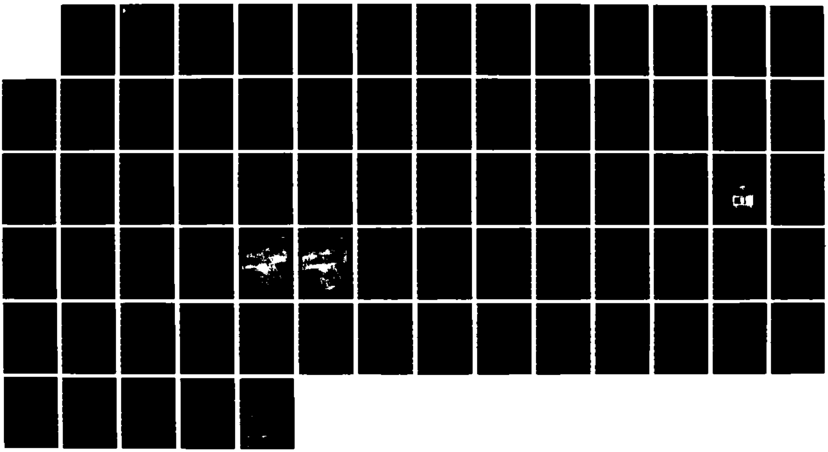

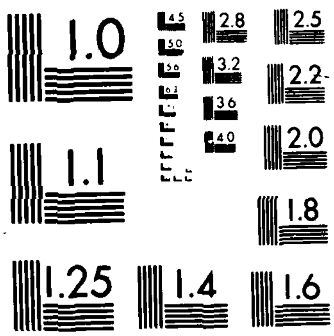
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Technical Report

THE MIDURA 1982-1983 EXPERIMENTAL TEST PLAN

AD-A172 410

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Radar and Optics Division

APRIL 1982

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report is an experimental test plan, a plan designed for use in exploring the utility of existing assets to detect the presence of both surface-laid and buried anti-tank mines and minefields and to aid in designing and specifying future minefield detection systems.

Flights are to be made by the Oregon National Guard OV-1D's using the AN/AAS-24 infrared scanner and the KA-76 camera for a period of a year over a

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20. ABSTRACT (continued)

minefield array at Camp Adair, Oregon. Other flights are to be made by the OV-1D's and Idaho Air National Guard RF-4's (AN/AAD-5 infrared scanner and the KS-87 camera) over selected areas representing other environments such as snow conditions and semi-arid and agricultural lands.

Flight schedules are arranged to match a matrix of parameter levels, parameters such as time of day, flight altitudes, mine type, weather conditions, etc. Instrumentation required for measuring the several variables and for calibrating the sensors are specified.

Data obtained in the tests are to be used for assessing image interpreter performance, for validating, revising and/or generating system models and for adding information to a minefield detection data base.

A description of the image interpreter evaluation test to be conducted is given.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Letter in file

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THE MIDURA 1982-1983 EXPERIMENTAL TEST PLAN

1 INTRODUCTION

1.1 MIDURA OBJECTIVES

The general objectives of the MIDURA (Minefield Detection Using Reconnaissance Assets) program are: (1) to evaluate and quantify the ability of currently operational or planned-to-be-operational reconnaissance assets to provide minefield information (2) to develop user guides in an operationally useful form to facilitate the use of these reconnaissance assets for provision of minefield information, (3) to explore viable means of detecting mines, and (4) to gain insight sufficient to guide decisions regarding utilization and upgrading of reconnaissance system capability for provision of minefield information. The experimental test program described below is designed to support these objectives and to aid in conceiving and specifying future mine and minefield detection systems.

1.2 EXPERIMENTAL TEST PLAN OBJECTIVES AND APPROACH

The experimental test plan objectives are:

1. To provide data useful in validating, revising and/or generating system component models. These system component models provide the basis for the mission planners guide.
2. To provide data suitable for developing a photointerpreter's guide.
3. To provide data gathered in a systematic manner for a data base to support the MIDURA objectives.

The experimental portion of the test program is based on the analyses and experiments performed under the predecessor contract as well as on the extensive experience and information which resides in the sensor and minefield detection communities. In the previous

program, much attention was given to relating physical characteristics of the targets and background, the environment, and the sensors to the detectability of minefields. A number of mathematical or measured relationships or models were established. These system component models generally are simple ones, often with forms not unlike transfer functions relating an output to an input through parametric quantities. The tests described below are for verifying the results predicted by these models, for model modification where models do not conform adequately to realistic operating conditions, for establishing new models, and for aid in determining the causes of unexpected results. The tests would be carried out with the goal of attaining peak sensor system performance when reconnoitering for minefields.

Under the current program, the engineering tests will be complemented by a series of tests designed to assess photointerpreter (PI) performance capabilities and restrictions. Test conditions are to be specified under an experiment design which relates interpreter performance through an image chain model to different levels of environmental conditions, to several flight regimes, interpretation conditions and to PI experience. The imagery obtained during these flights and from the interpretation experiments should enable system designers to pinpoint changes in those components or procedures which can lead to significant improvements in system performance. Further, by introducing the parameter values or by substituting new or modified system component models for determining input to the image chain model, the effects of hypothetical components or situations on interpreter performance can be investigated.

The results obtained from both engineering and PI evaluation tests will be added in a systematic fashion to the existing data base (data from Arrays I and II obtained prior to 1981). These data, along with system component models, will provide a basis for conceiving, designing and engineering new or modified sensor components or systems. Further, the data can be used to predict PI performance for these new or modified systems.

The data base will also provide the information on how and when current reconnaissance assets can be used to detect minefields. The results can be used as a basis for preparing user guides for aircraft and sensor operations.

2
SYSTEM ENGINEERING TESTS

Infrared scanners and cameras are the operational sensors to be tested for their ability to detect mines and minefields. Since such units have been in use for a number of years, there exists a substantial body of information on the operational capabilities of these sensors. The results of engineering tests must define the technical bounds in which these sensors can be used for successful minefield detection.

A systematic means for determining what engineering tests to perform and for designating parameter values in PI evaluation flight tests is to use an image chain model. An illustration of what is meant by an image chain for infrared scanners is provided in Figure 1. A similar image chain can be specified for photographic systems. With respect to minefield detection, the first link in the image chain is the mine/mine background. Included in this link are such factors as the mine type, the spectral response, the specular response, the temperatures of the mines, obscuration caused by vegetation, terrain type, and background temperature variations whose spatial frequency spectrum results in clutter at the system outputs. The second link in the chain concerns the atmospheric conditions. Such meteorological conditions as temperature, wind velocity, humidity, sunlight direction and cloud cover are included because they affect the observed temperatures; the atmosphere intervenes between the scene and the scanner. The third link involves the sensor characteristics. This link encompasses such factors as the types of sensor, the calibration of the sensor, as well as the sensor settings and the type of filters employed. The fourth link concerns the sensor platform, i.e., aircraft. Here, the concern is with the type of aircraft flying the mission, and the heading, speed, and altitude of that aircraft and the date and the time of flight. The fifth link

Sensor

FOV
Spectral bandpass
Sensitivity
Filter characteristics
V/h ratio
Resolution
Modulation Transfer Function
etc.

Airborne Platform

Direction
Speed
Altitude
Date and Time
etc.

Atmosphere

Temperature
Humidity
Wind speed and direction
Cloud cover
Transmissivity
etc.

Film Processing

Film Type
Chemicals
Refresh rate
Time
etc.

Target and Background

Mine temperature
Mine emissivity and reflectance
Soil type
Soil moisture
Soil temperature
Vegetation type
Vegetation density
Background spatial distribution
and variability

Interpreters

Optics
Light level
Experience
etc.

Measures

Image quality as functions
of IFOV, minimum detectable
temperature
Signal-to-clutter statistics,
etc.
Mine fields detected
etc.

FIGURE 1. SAMPLE IMAGE CHAIN FOR AN INFRARED SCANNER

regards the processing of the film, with such factors as the time, temperature, and refresh rate of the process. The sixth link in the chain is the interpretation process itself. Included here, in addition to such psychophysical factors as lighting and optics, are such issues as the training and experience of the interpreters themselves.

An image chain is a highly useful tool in assessing image quality and of assessing PI performance as discussed in Section 3. A chain is also useful in making certain that no important component, factor or operation is neglected when system engineering tests are performed. We note that while the chain progresses in a linear fashion when considering how an image is obtained and scrutinized, the factors which make up the chain interact among themselves in many instances. For example, weather conditions may affect mine and background temperatures differently.

One of the factors which cannot readily be controlled precisely is the time of flights over the minefield arrays. In order to obtain adequate and timely ground truth information, some automatic means is required for recording target and background temperatures and weather conditions. Similarly, aids such as resolution and gray scale calibration aids, must be available for use when flights are made. These ground truth and calibration aids are required to assess sensor performance in comparison to sensor specifications so that test bounds and test parametric values can be set. (Descriptions of the types of aids required are given in Appendix 1.)

Since mine and minefield detectability will vary during the four seasons, some of the system engineering tests will have to be repeated during each season to reflect changes in sensor performance because of weather and background conditions. It is likely, however, that many of the images obtained on flights made for system engineering purposes can be used for PI performance evaluation tests. In order to perform system engineering tests, it is necessary to take

advantage of existing and new models of system components. The system component models provide physical characteristic values for the links which tie together the image chain model from mines to interpreters. The modularity of these models allow the relative influence of the physical attributes to be assessed through the image chain model. The effects on image interpretability by modifying or replacing system component models can be assessed also.

One way of grouping the system component models is to couple mines and minefields with the backgrounds and propagation medium, the sensors and sensor platforms, and processors with interpretation. These groupings can then be broken down into sub-models. Examples of the details of the system component models are given below.

Mines and Backgrounds

Mine reflection and emission characteristics, both spectral and spatial, are characteristics which can be measured for each mine type under laboratory conditions. Other characteristics which can be predetermined include shape, size, material, paints, thermal capacity, and emissivity. The amount of energy reflected or emitted by a mine can be calculated using some of these predetermined characteristics along with either measured or estimated mine temperature.

Similarly, soil type, its spectral characteristics, the type and amount of vegetation, vegetation spectral characteristics are quantities which can be specified or measured. Contrast ratios between mines and ground can be calculated on either a deterministic or statistical basis if, in addition to the above characteristics, the ground temperature characteristics are known or assumed. For a given background condition, a contrast ratio can be calculated for each mine type. Conversely, for a given mine type, different backgrounds can be substituted and contrast ratios determined for these backgrounds. These ratios are inputs to the image chain models.

These models are essentially alike in the visible and optical portions of the spectrum except that emissivity and temperature are not of concern in the photo case.

Models representing buried mines are basically models of disturbed soil. All the characteristics discussed above under soil types would have to be specified or measured. Care would have to be taken to note whether vegetation is alive or dead. The effect of the buried mine on the soil characteristics would also have to be noted. Variations in minefield and background characteristics caused by long-term burial would also have to be noted.

Artillery scatterable mines are of special concern in that they may be dispersed either on their front or back; reflectivity and emissivity characteristics are likely to differ for the two sides and must be specified separately.

Minefields

The important characteristics of minefields are their size, the type of mines, the minefield pattern and mine spacings. These are characteristics specified by the assumed scenarios. Artillery scatterable mines will yield non-linear patterns; their extent will undoubtedly differ depending on the altitude at which the mines are dispensed.

Minefield patterns are of importance for recognition purposes whether by human or machine means. But in order to discern a pattern, some of the individual mines must be detected and false alarms must be kept to a reasonable number. Pattern recognition techniques which might be applicable include those for finding linear patterns and those for determining spatial frequency characteristics. Thus, the minefield characteristics must be carried throughout the image chain.

While buried mines cannot currently be directly detected by remote means, strips plowed by mechanical means or individual holes dug by hand present patterns which, in some instances, are discernible for long periods of time. For buried mines, it is these patterns of disturbed soil and vegetation which must be carried throughout the image chain.

Propagation Medium

The atmosphere and weather affect contrast ratio and transmissivity. The contrast ratio is affected by temperature, wind, haze, cloud cover and sun direction, quantities which are measurable and/or calculable. Their effect on mines and background temperatures is measurable so that for any given set of weather conditions, contrast ratios between mines and background can be measured or specified.

Atmospheric transmission is high under good weather conditions. Under poor weather conditions as in fog, transmission can be low. The LOWTRAN model is a good example of atmospheric transmission models. The application of existing calculations using this or other models to the minefield detection problem should indicate whether or not atmospheric transmission is a negligible factor.

Sensor

Those characteristics which describe an infrared scanner model include the field of view (FOV), the instantaneous field of view (IFOV), resolution, detector type, its noise equivalent temperature (NEΔT), number of detectors, detector spectral bandpass, filter types and their bandpass characteristics, gain settings, dynamic range, linearity, modulation transfer function (MTF), recorder characteristics, and V/h ratio. For cameras, the important characteristics include film type, its resolution, aperture, focal length, shutter speed, filters and their spectral bandpass and the V/h ratio. (The

V/h ratio is used as an input to the forward motion compensation control system.) Filter and film selection is discussed in Section 3.2.

Detector/filter and film/filter spectral characteristics are of importance in terms of how they affect the existing contrast ratios between mines and background. The FOV's and resolution capability can be coupled through the sensory access model derived in the previous contract to specify the altitudes which should be flown to assure detectability and to maximize swath width. Once altitudes have been selected, it is a simple matter to calculate whether or not the maximum V/h ratio is exceeded. Gain settings for the infrared scanner adjusts the dc level so as to be able to detect the ac components.

Another factor which affects sensor resolution is vibration. Sensors must be isolated from high frequency aircraft vibrations if the maximum resolutions of which sensors are capable are to be maintained. It is expected that cameras which can achieve fine resolution will be affected more by vibration than will scanners with less resolution.

Platform

Those characteristics of the platform, important in the image chain, are the altitude, speed, and direction of flight as well as minimum flight conditions. Altitude and speed are set by the sensor characteristics. For photographic purposes, sun direction and the direction of flight are important for enhancing contrast ratio. It is likely, however, that terrain characteristics and in some cases, enemy troop dispositions may have major influence on the choice of flight direction.

Other platform characteristics such as endurance, navigational ability, data links, vulnerability and survivability, and availability are associated more properly with the C^3I model for assessing the duration required to carry out a minefield detection mission.

The primary platform during the tests will be the OV-1D Mohawk. It is expected that USAF RF-4's will participate in some of the tests.

Processing

Film contrast dynamic range is limited and film processing equipment and chemicals can play a large part in attaining good contrast. Some films should be processed by the Oregon National Guard and others at ERIM in order to have at least two independent assessments of processing effects on image quality.

Interpretation

Those aspects of the interpretation process which require modeling are physical characteristics such as the optics used, the lighting level and subjective characteristics such as experience level. Physical characteristics are given or can be measured. PI experience and image rating scales are more subjective in nature; in these instances, the models devised must rely heavily on models used in the past for interpretation of objects other than mines and minefields.

3 FLIGHT TESTS FOR PHOTOINTERPRETER EVALUATION

One of the prime goals of this study is to determine how well photointerpreters can detect the presence of a minefield. To achieve this goal, data must be obtained over a variety of weather, background, sensor and flight conditions and the imagery obtained must be scrutinized by a number of photointerpreters. Basically, two populations are being dealt with in a statistical manner. One population are the sets of imagery collected under different combinations of test conditions and the second population are the photointerpreters.

3.1 EXPERIMENT DESIGN

An experiment design provides a meaningful way to relate the interaction between the two populations. The test conditions are controllable independent variables whose levels can be set or uncontrollable variables whose levels must be measured. Photointerpreter performance can then be assessed in terms of the several combinations of the levels of the variables. From these results, inferences can be drawn on the relative effect of each variable on photointerpreter performance. The number of replications required for a given combination of levels is a function of the magnitude of the effect of each particular variable and the variability (error or noise) surrounding its collection. If the effect is strong and the variability is low, few replications are required. Conversely, if the effect is weak and the variability is high, many replications are required. As the experiment progresses, those variables whose effects are strong will quickly become apparent. There will be some parameters whose effects are weak and also with low variability. Once these two types of parameters have been identified, the levels tried and the replications repeated can be concentrated on those

parameters with weak-to-medium effects and with medium-to-high variability.

3.2 EXPERIMENTAL DESIGNS FOR ARRAY II

Descriptions of the underlying experimental designs for the IR and photographic PI experiments follow. Both experiments are planned to run for one year. The week is one of the fundamental sampling units for the experiment so that the cells or parameter levels within each experimental design are to be filled when possible on a weekly basis. Portions of mine arrays are to be moved on a bi-weekly to quarterly-year basis with the movement time dependent on the number of passes flown. Any cells in the design which can be eliminated on a priori grounds will be as that will simplify the data collection effort. Once the imagery has been collected, it will be screened and evaluated at ERIM, and then distributed for interpretation.

The basic IR design is a 2 (flight altitude) by 6 (flight time) factorial design yielding a total of 12 experimental cells to be filled on a weekly basis. The basic photographic experiment design is a 3 (flight altitude) by 6 (flight time) factorial design yielding a total of 18 experimental cells. The levels of the factors are discussed under their respective headings under Controlled Independent Variables. With the exception of the location of the film processing, the other controlled factors (e.g., mine types, minefield size) will be randomly varied within the basic design according to prestated restrictions.

3.2.1 CONTROLLED INDEPENDENT VARIABLES

This section lists and discusses the independent variables which will be manipulated according to schedules developed by ERIM. These variables are to satisfy the requirements for both objective and subjective tests.

Mine Location and Type

Twenty-four PM60 mines, 24 M15 mines, and 24 artillery scatterable mines are to be placed on the surface and 24 PM60 and 24 M15 are to be buried. Six to 12 of the surface positioned mines will be moved on a bi-weekly basis. The buried mines will be moved less often, perhaps on a monthly to quarterly basis, depending on the recovery time of ground scars. Three levels of each mine type subarray will be zero (no mines), 12 and 24 mines. These sizes will be varied randomly on a bi-weekly basis with the restriction that each size be sampled equally, often within successive 12-week periods.

Flight Definition

A flight mission or sortie is defined as a flight with one takeoff and one landing. During a mission, an aircraft may make several passes over an array. An infrared scanner makes a continuous image during each pass. A camera takes a number of photographs or frames per pass.

Flight Altitude

For IR collection, two levels of flight altitude, high and low, will be employed. High altitude is defined as 800 ft AGL and low altitude as 500 ft. The choice of 800 ft is based on results of previous flights over Arrays I and II and on theoretical considerations of resolution capabilities. The 500-ft altitude is based on the fact that the scanner optics will be out of focus below this altitude and on VFR flight considerations.

The initial choice of altitudes for the KA-76 camera experiment are 800 ft and 1200 ft, based on the photographs of Array II obtained during 1981. Photographs should be taken on infrared missions at 500 ft to take advantage of the flights at a third altitude. Results of recent flights over Array II indicate that 30 to 35 lines/mm of resolution is being achieved. System engineering tests will be

performed with calibration aids to further ascertain resolution capability. Flight altitudes for the PI experiments will be chosen on the basis of these engineering test results.

Photographs are to be taken at all three altitudes. Some infrared imagery should be taken at 1200 ft to verify that mines cannot be detected from this altitude.

Flight Direction

Flights over Array II at Camp Adair will be on a heading of 305° magnetic, 325° true. The flight path chosen avoids aircraft noise problems over populated areas.

Flight Times and Dates

Approximately 40 flights were made by the Oregon National Guard during the period 8 April through 4 September 1981 or an average of close to two flights per week. A total of 199 frames (passes) of infrared imagery were obtained on those flights or an average of 5 passes per flight. Based on these averages, at least 96 flights and 480 frames of infrared imagery can be expected assuming 48 weeks of operation.

In actuality, five or six flights per week may be possible during the late spring, summer and early fall. If four flights per week are made over a 26-week period and two flights per week for the remaining 22 weeks of expected operation during a year, a total of 592 passes or frames of imagery would be obtained assuming four passes per flight. These flights should contribute about 400 to 600 images to the data base during the course of one year.

For the infrared scanner, it would be desirable to have flights during the night as well as day. Experience shows that many previous flights were made in the evening (after 5 o'clock) or late mornings because of the pilots' civil work schedules. Because infrared contrast should be greatest near mid-day, it is suggested that flights

during the mid-morning through mid-afternoon periods be scheduled whenever possible such as on weekends, perhaps one flight on every Saturday and Sunday.

Mines have not been detected with the infrared scanner or the limited number of night flights made to date over Arrays I and II. Temperature contrasts between mines and background appear to be sufficient for mine detection at certain periods of the night provided correct gain settings are used. Further engineering tests should be flown at night during each season to determine scanner capability at night. Whether extended night flights are required can be based on the results of these tests and on ground truth measurements of mine and background temperatures.

The Mohawk is equipped with both regular and covert electronic flash units which can be operated to take photographs at night. The regular flash unit is not operated frequently in populated areas because of complaints from the public. It is suggested that several engineering tests be run to determine KA-76 capability for imaging minefields at night using both the regular and covert flashers. Near infrared sensitive film is required for use with the covert flasher.

The scanner and camera should be operated simultaneously during daytime and night flasher missions.

Filter and Film Selection

The AAS-24 scanner has five filter positions which can be used. Based on filter, detector and atmospheric considerations, component models indicate that only two of these positions can yield useful signals and filter-to-noise ratios. (The models consist basically of the spectral bandpass transmission characteristics of the filters, detector and atmosphere and are described in the memorandum by C. Due entitled, "Optimizing the Spectral Response of the AN/AAS-24 Infrared Line Scanner for Use in Land Mine Detection (U)," 15 December 1981.) One of these positions is an open position with no filter; the other position has an 4.5 to 14 μm filter which yields

slightly lower signals and signal-to-noise ratios than the open position. A system engineering test should be performed to verify this theoretical conclusion. If the open position is even marginally better than the 4.6 to 14 μm filter position, the open position should be used in all other tests.

It is recommended that KA-76 camera system engineering tests be run with EKC 2402* medium speed, high quality black and white panchromatic film, EKC 2424, infrared sensitive, black and white film and with EKC 2443 false color (infrared sensitive) reversal aerial film. Earth disturbed by mine burial may prove to be more easily discerned with the color film. The six inch focal length lens should be used.

These system engineering tests should be performed during each season. The choice of films to be used in the flight tests for PI evaluation purposes, should be based on the results of these system tests.

The initial choices of film-filter combinations for detection of buried mines and minefields will be based on the results reported in the Broadview Research Corporation reports listed below.

> "Minefield Detection in Aerial Photography in Desert and Steppe Environments (U)," Final Report, Report No. BRC-136-13, (ASTIA 324723), June 1960, CONFIDENTIAL.
>
> "Minefield Detection in Subarctic Environment (U)," Final Report, Report No. BRC 150—11 (ASTIA 324724), December 1960, CONFIDENTIAL.
>
> "Minefield Detection by Aerial Photography in Mid-Latitude Environments (U)," Final Report, Report No. BRC 157-9, (ASTIA 324722), July 1961, CONFIDENTIAL.

*GAF 2914, a Plus-X film whose characteristics are essentially the same as EKC 2402 may be used in place of the latter.

These choices may be modified based on findings of Subtask 2k (film/filter combinations) and operating experience.

Infrared Scanner Gain Setting

Three of the four available gain settings should be tried in a series of system engineering tests. One setting (Position 1) should be used when expected contrast is high as during mid-day hours on sunny days and Position 2 should be used when contrast is low as at dawn and dusk or at night. The AGC position may be expected to yield good imagery because a large temperature variation is not usually expected over a minefield. Based on the results of these tests, two or all three of the settings will be chosen for use in the photo-interpreter evaluation flight tests.

The target mode setting should be on the position "Cold Target".

Film Processing

Film should initially be processed under system engineering tests by both the Oregon National Guard and by ERIM to determine if any image quality differences exist. The choice of where the remainder of the images are to be processed or what chemicals are to be used should be based on the results of these tests.

Infrared and color film processing will be done either at ERIM or commercial laboratories.

3.2.2 UNCONTROLLED INDEPENDENT VARIABLES

Those factors listed and discussed below are deemed either unfeasible or inadvisable to control; nevertheless, these factors need to be recorded throughout the course of the experiment since they can profoundly affect PI performance. Means of collecting and recording these data are discussed in Appendix 1. Table 1 is a summary of the several independent controllable and uncontrollable variables.

TABLE 1
PRELIMINARY LIST OF INDEPENDENT VARIABLES

Note: The following key indicates wehre each variable is located on the Image Chain

(MB = Mine Background; A' = Atmosphere; S = Sensor; AC = Aircraft; P = Process, I = Interpretation)

Variable/Measurement	Controlled Observed	Levels/Continuous	Source	Method of Measurement
Collection Variables				
IR Altitude (AC)	Controlled 1:1000-800	500; 800 ft Plan; Flight 3:500-800	Collection Minefield Pass	Altimeter During Minefield Pass
Photo Altitude (AC)	Controlled	To be Decided	Controlled Plan Flight Log	Altimeter During Minefield Pass
Photo Film Types (S)	Controlled	2402; 2914; 2424	Collection Plan, Flight Log	N/A
Vegetation of Mines (MB)	Observed	Continuous	Ground Truth	Mean of 20 Height Measurements Taken at Random Locations in Minefield
Flight Line A/C)	Controlled	Flight Log	Cockpit Compass	
Mine Array Variables				
Mine Temperature (MB)	Observed	Continuous	Ground Truth	Surface Temperature of Mine in Test Array
Location (MB)	Observed	6-8 Pre-Surveyed Minefields	Ground Truth	Survey, Photographs
Spectral Response (MB)	Observed	Sampled	Laboratory	Spectroradiometer
Mine Image (I)	Observed	Continuous	Image Analysis	Size, Ellipticity, Intensity
Separation of Mines on Image (I)	Observed	Continuous	Image Analysis Ground Truth	Separation Length

TABLE 1 (Continued)
PRELIMINARY LIST OF INDEPENDENT VARIABLES

Variable/Measurement	Controlled Observed	Levels/Continuous	Source	Method of Measurement
Mine Array Variables (Cont'd)				
Linearity of Rows on Image (I)	Observed	Continuous	Image Analysis Ground Truth	Measure Deviations from Line-Fit
Relative Angle of Rows (MB)	Observed	Continuous	Image Analysis Ground Truth	Protractor Survey
Geometry (MB)	Fixed	Single Array	Collection Plan Ground Truth	N/A Survey
Background Temp. (MB)	Observed	Sampled	Ground Truth	Radiometer Measurement
Atmospheric Variables				
Time of Day (A)	Controlled	3-hr Block	Flight Log	Cockpit Clock
Sun Position (A)	Observed	Continuous	Flight Log	Time/Angle
Air Temperature (A)	Observed	Continuous	Weather Station	Drum Thermometer
Wind Speed (A)	Observed	Continuous	Weather Station	Anemometer
Precipitation (A)	Observed	Continuous	Flight Log	Presence/Absence
Humidity (A)	Observed	Continuous	Weather Station	
Dew (A)	Observed	Presence/Absence	Weather Station	
Snow (A)	Observed	Continuous	Weather Station Ground Truth	
Volcanic Dust (A)	Observed	Presence/Absence	Ground Truth	
Season (A)	Observed	Date	Flight Log	Julian Date
Cloud Cover (A)	Observed	Broken	Flight Log	

TABLE 1 (Concluded)
PRELIMINARY LIST OF INDEPENDENT VARIABLES

Variable/Measurement	Controlled Observed	Levels/Continuous	Source	Method of Measurement
Sensor Variables				
Photo vs. IR Scanner	Observed	Photo; IR Scanner	Flight Log	N/A
Photo Camera Lens	Observed	f Stops	Flight Log	
Photo Camera Shutter Speed (S)	Observed	Speed Stop	Flight Log	
IR Scanner Setting	Controlled	3 Levels	Collection Plan	
IR Filters (S)	Controlled	5 Levels	Collection Plan	N/A
Processing Variables				
Location (P)	Controlled	ERIM; ONG	Collection Plan	N/A
Time (P)	Controlled		Processing Log	Timer
Temperature	Controlled		Processing Log	Thermometer
Refresh Rate (P)	Controlled		Processing Log	Flow Motor
Material Type (P)	Controlled	IR Scanner Photo Camera Film	Collection Plan	

Ground Truth Variables

With the exception of the mine locations, the ground truth variables are uncontrolled and need to be documented meticulously. For each overflight the following ground truth needs to be obtained: (1) date and time of overflight; (2) mean ground temperature; (3) mean PM60 temperature; (4) mean M15 temperature; and (5) mean scatterable mine temperature.

Meteorological Data

Both general and local meteorological data need to be recorded. General met data refers to the ambient conditions during the time of the flight. Local met refers to the met conditions at the array at the specific time of the overflight.

Aircraft and Crews

For each flight the aircraft/scanner/sensor employed and the pilot and operator for the run should be documented.

Airspeed at Time of Overflight

The controlled variables of airspeed, altitude, heading, and time of each overflight should be recorded.

3.2.3 PHOTO EXPERIMENT MATRIX

The photo experiment matrix is a combination of three altitude levels, six time-of-day intervals, three levels of the number of mines and three mine types for the surface-laid mines (Figure 2). The total number of combinations possible are 162. For the buried mines, there are only two mine types with 24 mines of each type being buried. The total number of combinations is 36.

A matrix as shown is planned to be filled during a two-week period. Successive matrices would be filled on a bi-weekly basis because some of the surface-laid mines are planned to moved every two weeks. Moreover, multiple iteractions are required to sample adequately meteorological and seasonal variations.

TIME OF DAY INTERVALS

		EARLY MORNING			MID-MORNING			NOON			MID-AFTERNOON			LATE AFTERNOON			NIGHT		
		NO OF MINES			NO OF MINES			NO OF MINES			NO OF MINES			NO OF MINES			NO OF MINES		
	ALTITUDE (ft)	0	12	24	0	12	24	0	12	24	0	12	24	0	12	24	0	12	24
		PMS	PMS	PMS	PMS	PMS	PMS	PMS	PMS	PMS	PMS	PMS	PMS	PMS	PMS	PMS	PMS	PMS	PMS
SURFACE	1200 - 1600																		
	800																		
	500																		

		EARLY MORNING		MID-MORNING		NOON		MID-AFTERNOON		LATE AFTERNOON		NIGHT	
	ALTITUDE (ft)	NO OF MINES 24		NO OF MINES 24		NO OF MINES 24		NO OF MINES 24		NO OF MINES 24		NO OF MINES 24	
		P	M	P	M	P	M	P	M	P	M	P	M
BURIED	1200 - 1600												
	800												
	500												

Figure 2. Photo Experiment Matrix

P - PM 60, M - M 15, S - Artillery Scatterable Mines

The time intervals during which flights should be made will be specified on a monthly basis to account for seasonal variations. A simplified experiment plan encompassing both sensors will be submitted monthly to the Oregon National Guard in order that flights may be planned. These simplified plans will indicate altitudes and times of day when flights would be desirable.

It is suggested that on any given flight, the successive passes should be at the different altitudes. At a minimum, six flights during a two-week period, is theoretically sufficient to fill a matrix. More flights would be welcome in order to fill any level combinations which may not have been filled for any reason such as a portion of the minefield not being in the camera field of view. Also, data obtained from imagery obtained under like conditions, provides greater confidence in the results. The important factor however, is to fill as much of the matrix as possible every two weeks.

Film type has not been included as a parameter. The effect of film type on detectability will be examined under a series of engineering tests in which different films are used under like conditions in favorable weather. These engineering tests will entail additional flights.

Uncontrollable variables such mine temperatures and the weather conditions will be monitored.

It is expected that as the test progresses, there will be adjustments made in the number of levels of the several parameters with a goal of reducing the number of levels which need to be tested. If such reductions can be achieved, the Oregon National Guard will be notified as soon as possible.

3.2.4 PHOTOINTERPRETATION EVALUATION

As the image interpreter (II) is an integral system component, II evaluations provide essential inputs to the MIDURA data base.

This data base will, in turn, serve to develop/refine the system component models as well as to provide the basis for the Mission Planner's Guide.

Two types of imagery evaluations will be conducted: objective and subjective. Objective evaluations are, quite simply, actual performance assessments of target (i.e., minefield) detection by II's. The term objective is used because the measured performance is observable; e.g., number of mines detected. Very often, however, it is difficult to perform valid objective evaluations. If the II's have access to ground truth, become familiar with the terrain/target location, communicate among themselves, or otherwise are "contaminated," obtained II performance will be biased and inflated. Subjective evaluations have proven quite useful in such situations. These subjective evaluations require participating II's to estimate the probability that trained II's would currently detect a target for a given piece of imagery. The subjective estimates have been shown to provide valid estimates of actual II performance. Such a procedure enables one to collect more data with greater sensitivity than is the case for objective measures, permitting formation/revision at component models with a continuous criterion variable (e.g., probability of detection).

A detailed rationale for the Image Interpreter Evaluation is provided in a separate document entitled, the MIDURA Image Interpretation Evaluation.* In addition to presenting the image interpretation evaluation plan, this document provides a brief background regarding a number of related topics which are pertinent to the evaluation. Among the topics discussed are psychophysics, subjective methodologies, and the relationship between subjective estimates of performance and obtained II performance. Alternative experimental

*J. Leachtenauer, T. Bevan, and D. Griffith, "MIDURA Image Interpreter (II) Evaluation, Internal Memorandum SP-82-2089, Environmental Research Institute of Michigan, April 9, 1982, UNCLASSIFIED.

designs are discussed along with the resource requirements associated with each design. Included here is the justification for the preceding plan.

The proposed Image Interpretation Evaluation Plan involves the following three phases: (1) subjective image interpretation at ERIM; (2) subjective validation at the Salem ONG; (3) objective validation at Fort Huachuca.

3.2.4.1 Subjective Image Interpretation at ERIM

The initial phase of the evaluation involves the subjective image interpretation of all collected image representative of the experimental matrix by five ERIM II's. The ERIM II's will provide for each image estimate of P_D, P_C, and P_{FA} on a 0.00 to 1.00 scale. P_D is defined as the subjective probability estimate that an operational II will make a correct response given E_p^*. P_C is the estimated probability of a correct response given E_{NP}**. P_{FA} is the estimated probability of an incorrect response given E_{NP}. Image interpretation can begin at ERIM as soon as documented imagery arrives from Oregon.

Prior to performing any ratings, a scenario and a training package will be developed. The scenario will define assumptions regarding the operational situation. The training will define the interpretation cues to be furnished for training II's in the objective portion of the evaluation.

An additional issue which must be resolved is the estimating unit, i.e., full image vs. sub-image area. Given the expected (as opposed to desired) number of images likely to be available, it is expected that the sub-image concept will be required. This will also

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*E_p = the presence of a mine/minefield.

**E_{NP} = the absence of a mine/minefield.

normalize search area across image scale and thus avoid (for purposes of model development) a difficult confounding effect.

The subjective ratings will be used as the dependent variables in the initial statistical analysis. Stepwise multiple regression will be used to develop prediction equations which will serve as the primary empirical input to the MDM. These prediction equations will also provide the basis for formulating guidance for the Mission Planner's Guide.

At this point, questions still can be raised about the internal validity (more frequently referred to as reliability) of the subjective minefield detection metric. The issue here whether this metric is idiosyncratic to ERIM II's, or whether it is readily generalized to the universe of II's.

3.2.4.2 Subjective Validation at the Salem ONG

The second phase would involve taking a representative sample of, say, 60 images to the ONG II's. After undergoing a two hour training session conducted by ERIM pesonnel, the ONG II's would perform the same rating task (under the same scenario conditions) that was performed by the ERIM II's. Two basic analyses would be performed by the Oregon II data. The first would be the simple zero order product moment coefficient between the mean ERIM rating and the mean ONG II rating for each image. This statistic provides an image of the extent of agreement between the two groups. The second analysis would be a chi square goodness of fit test between the ERIM prediction equations and the rating obtained from the ONG II's. In addition to answering questions regarding how good the ERIM predition equations are, these analyses will also indicate whether transformations need to be applied to the data and, if so, what those transformations should be.

It should be noted that the validation process does not require validation of the effects of the variables, but rather the ERIM II's scaling of those variables. The sample process can thus be based largely on P_D, P_C and P_{FA} levels as opposed to the independent variables per se. Some sampling of the measured physical quality domain would also be performed.

At this point the internal validity of the predictive equations will have been established, and any required transformations or changes in those equations will have been made. However, the issue of external validity can still be raised. That is, the issue of how useful these equations are in prediction II performance.

3.2.4.3 <u>Objective Validation at Fort Huachuca</u>

At Fort Huachuca, student, and if they can be obtained, instructor II's would interpret, after they have received a two hour block of instruction on minefield detection, representative imagery. For the buried minefield case, an interpreter would view an image showing E_p no more than once per minefield location. Where E_{NP}, as many images as time permits could be viewed (without bias). For the surface mine case, some modest increase in the number of trials would be possible. It is anticipated that the probability of $E_{NP} > E_p$, but the precise ratio is TBD. It can be argued that, with an intelligent mission planner (i.e., one with a priori knowledge regarding likely minefield locations), the probability of E_p could be quite high. From a methodological viewpoint, it would be best to equate the conditions of E_p/E_{NP}. The decision on the ratio to be used should best await a view of available imagery, although every attempt should be made to obtain a representative sample of images where E is true.

The number of II's available is unknown. It must be assumed that a minimum of 10 independent responses are required per experimental

cell. Given the previously stated restrictions, each interpreter could view an image where E_p is true approximately 5 times, and where E_{NP} is true, as many times as desired. On this basis, four groups of 10 II's each would be sufficient to evaluate 20 experimental cells where E_p is true. Since it is the subjective response function rather than the model which requires validation, the number of cells requiring validation is substantially reduced. For each image containing minefields an empirical probability of minefield detection would be computed across II's. Similarly, for each image not containing minefields an empirical probability for false alarm, and P_C would be computed across II's. Then, just as in the case of the subjective condition, zero order product moment correlation coefficients would be computed between the mean ERIM ratings and the obtained objective scores for each image. Then chi square goodness of fit tests would be done between the predicted and the obtained scores.

It should be noted that the objective responses will differ slightly from the subjective. In the objective case, the II's will be asked to assess the probability that a minefield is present and the probability that one is not present. No direct estimate of P_{FA} will be made by the II's.

4
TEST FLIGHTS AT ARRAYS IIa, IIb, IIIa AND IIIb

A number of candidate sites have been identified for representing either a European or a semi-arid environment. These sites and their associated array numbers are listed in Table 2.

The number of test flights at Mary's Peak or an alternate site at Santiam Junction Airstrip (Array IIa), Hyslop Farm (Array IIb) and Arrays IIIa and IIIb will be limited in number. These tests will be designed primarily as system engineering tests in order to test the effects of different backgrounds and environments. Where possible as at Arrays IIa and IIb, the tests will be designed to be subsets of the main set of PI evaluation tests at Camp Adair, Array II. If weather and flight conditions permit, passes will be flown over all portions of Array II on the same flights.

The portable weather instrumentation is expected to be moved on occasion to these several array sites in order to obtain good ground truth data.

Arrangements are expected to be made with the Oregon National Guard and Idaho Air National Guard to fly missions over Arrays IIIa and IIIb. RF-4s equipped with AAD-5 infrared scanners and a photographic suite would be used by the Idaho Air National Guard.

TABLE 2
ARRAY SITES

Array Number	Array Locations: European Analogue Environment	Array Locations: Semi-Arid Environment
II	Camp Adair	—
IIa (snow environment)	Mary's Peak or Santiam Junction	—
IIb (farm crop environment)	Hyslop Farm	—
IIIa	—	Yakima

APPENDIX A
GROUND INSTRUMENTATION AT ARRAY II

1.0 INTRODUCTION

The ground instrumentation and aids will be used for the three purposes of measuring environmental conditions, of calibrating sensors, and of providing flight aids. These three sets of instruments and aids are described in the following sections.

2.0 INSTRUMENTS AND AIDS FOR MEASURING ENVIRONMENTAL CONDITIONS

Quantity	Weathertronics Model	Item Description
3	11502	Cassette Tape Recorder
2	1151	Remote Data Acquisition System - (including) interval signal conditioning, program library, LED display and 16 keypad, gel cell battery and battery eliminator
1	600505	10 ft humidity and temp cable
1	600504	10 ft solar radiation cable
1	11503	Digital Printer
2	170452	Cassette Tape Recorder Cable
1	170454	Digital Printer Cable
1	11510	Lead Battery
1	2020	Micro Response Wind Vane
1	2032	Anemometer
1	2023	Cross Arm
1	8160	Vane Aspirated Radiation Shield
1	30317-99	Boom
1	5121	Humidity and Temperature Probe
1	11505	Differential Amp
1	51137	Sintered Filter
1	3020	Star Pyranometer
1	30310	Mast

Quantity	Weathertronics Model	Item Description
1	600503	10 ft Wind Direction Cable
1	600504	10 ft Wind Speed Cable
1	996025	Battery Pack for Tape Recorder
12	996026	Cassette Tape
2	8500	Tripod Tower
1	85000	Mast for Cross Arm
10	4480	4 Wire Thermistor Probe

The Weathertronics Automatic Weather Station is illustrated in Figure 3. The solar cell power suply is not being purchased.

Quantity	Item Description
1	Shadow Target (Section 3.0)

3.0 SHADOW TARGET

The shadow target is envisioned for several purposes (Figure 4). The length of the shadow in the imagery could be used to calculate the time of day. The amount of scattered light in shadow in relation to combined direct and scattered lighting outside of the shadow can also be determined. The angle between sun direction and aircraft direction to the pole can be determined by ascertaining aircraft nadir from the photographs taken with the KA-76 camera.

The shadow target consists of a prepared smooth background (cleared of vegetation), a vertical pole and markers of the cardinal compass points (True N, S, E, and W). The pole should be eight feet above ground and within a few degrees of vertical. Height of the pole should be known to the nearest inch. The pole should be about twelve or more inches thick. The background should be uniform in tone and color and should extend a radius of 20 feet from the pole. This background can be truncated five feet to the south of the pole since shadows will not occur there. The markers for the compass

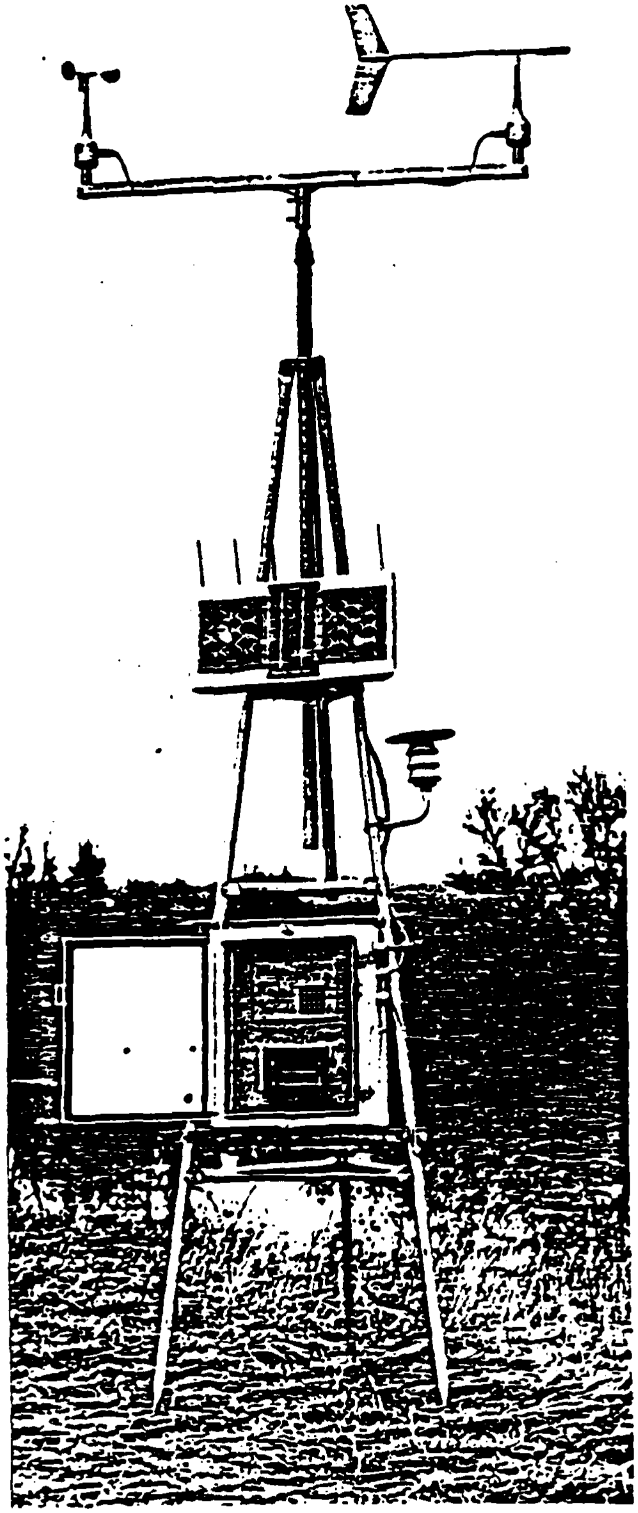


Figure 3. Weathertronics Automatic Weather Station

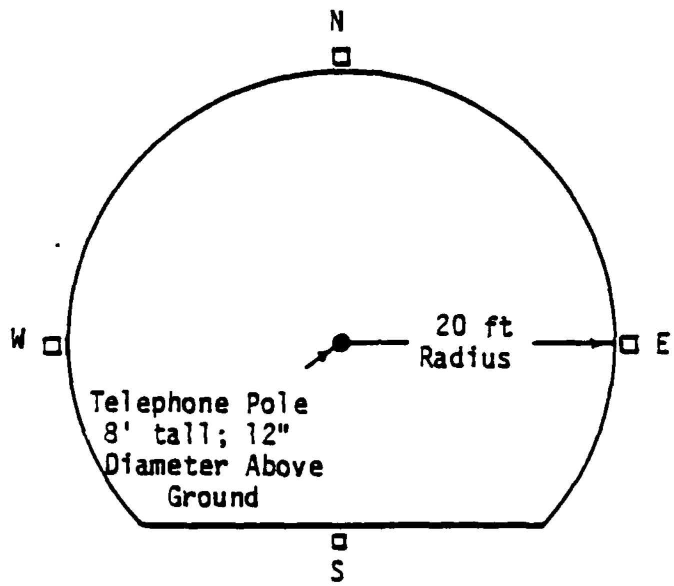


Figure 4. Shadow Target

□ True North, East, South, West Markers;
White, 12" Diameter

Telephone pole should be mounted to within $\pm 3°$ of vertical. The slope of the ground around the pole should be determined to $\pm 3°$

Surface within shadow area should be smooth and free of vegetation. The spectral reflection should be uniform. The subsoil from the telephone pole hole should be distributed elsewhere if it does not match surface soil spectrally.

points should be bright and about twelve inches across. The South marker should be placed where the prepared background ends.

The resolution and gray scale panels should be placed south of the pole to assure their freedom from the pole shadow.

A wind sock could be placed at the pole top to aid in assessing wind direction for infrared calibration purposes. If a wind sock is used, the dimensions of the installation should be documented.

4.0 SENSOR CALIBRATION AIDS

Ground targets with known characteristics are required to establish the operating characteristics of the sensors at the time of minefield data collection under the same environmental conditions as those under which mines are to be detected. Separate calibration aids are required for camera systems and for infrared scanner systems.

4.1 PHOTOGRAPHIC CALIBRATION AIDS

Two photographic calibration aids are recommended, one for measuring resolution capability and one for determining contrast capability. Suitable aids are available from the firm General Image Engineering Corp. (GIE). A 10 ft by 18 ft, high contrast three-bar resolution target (RST-7601) appears ideal for calculating achieved resolution of the camera-film-aircraft-processing combination. This target is made of a non-woven fabric with a matte surface. The ground resolved distances between bars vary in width from 3/4 inch to 12 inches. This target also provides orthogonal bars that permit determination of resolution in two directions. This arrangement is useful for discerning forward motion compensation (FMC) problems. The contrast is 20:1.

A gray scale with controlled reflectance is necessary for film calibration on photographic missions. The RST-7605 is a neutral

6-step gray scale covering a reflectance range from 64 percent to 2 percent or 5 stops of exposure. Each reflectance level section is 5 x 6 ft and they are assembled to form a single 10 x 18 ft panel.

The bar target along with the gray scale contrast calibration target can be placed within or near the fenced-in compound. The bar target should be placed in line with the flight line going roughly NW (305° Magnetic). Whether the long or short dimension of the target is in line with the flight track does not matter because the target is small in relation to the field of view of the cameras. If within the compound, both targets should be at least 16 ft from the southern fence edge and at 20 ft from the eastern and western edges to avoid shadows. The targets should also be at least four feet from the northern edge of the fence due to angle of sight considerations.

The ground below the targets should be smooth and free of sharp objects. Coarse vegetation should be removed. A bed of gravel (without sharp edges) would help keep the area from getting muddy during wet periods and dusty during dry periods. The targets should be mounted flush to the ground to prevent wind from getting under the targets. They should be flat and without ripples. Frames, such as sold by GIE would be helpful for holding the targets taut and for staking them to the ground.

The calibration targets should be examined regularly, e.g., bi-weekly, to check for visual changes in appearance. Reflectances of both resolution and calibration targets should be measured with a hand-held radiometer every ninety days or more often if changes are apparent, in order to measure changes caused by exposure to sunlight and weather. Background will be excluded by making measurements at short ranges. Target recovery is recommended if periods of one or more weeks without flying are anticipated.

4.2 INFRARED CALIBRATION AIDS

Two water pools and an aluminum plate are to be used to measure the temperature response of the sensor. One pool should be at ambient temperature; the other pool should be 6 to 10°C warmer. The thermostatic control on the heated pool can be set to operate on the temperature differential. The aluminum plate should be painted white to provide a temperature reference below ambient temperature.

The square pools should be a minimum of 5 to 6 ft on each side and a minimum of 6 inches in depth. Each pool should be provided with a heater and a water circulator. (The heater in the ambient temperature pool would be used to prevent ice formation in freezing weather.) Fish tank bubblers may suffice to provide sufficient circulation to maintain temperature uniformity. One set of pool and aluminum plates sides should be set parallel to the flight line.

A board placed between the two pools is to be used to measure the sensor MTF. The board should measure 4 ft by 8 ft with the 4 ft edge placed parallel to the flight line. The board should be painted olive drab and the 4 ft edges should overhang the edge of each pool between 1 and 3 inches.

A set of six round, wax-filled, targets are to be used to measure the minimum resolvable temperature difference required for the photo-interpeter system to detect mines with respect to altitude. These should be placed in a 20 ft diameter circle along with the mines whose temperatures are to be measured.

5.0 FLIGHT AIDS

Flights will be made along a heading of 305° magnetic, 325° true. Parallel flight lines along these headings may be used in order to make certain that the mines are within the sensor's fields of view.

A pole equipped with a light for night mission purposes is already at Camp Adair. It is believed that this marker is sufficient as a suitable flight aid.

Figures 5 and 6 illustrate the expected swath widths to be covered by the infrared scanner and the camera respectively assuming the flights are made at the indicated altitudes. Minefield placement will be based on these indicated coverage areas.

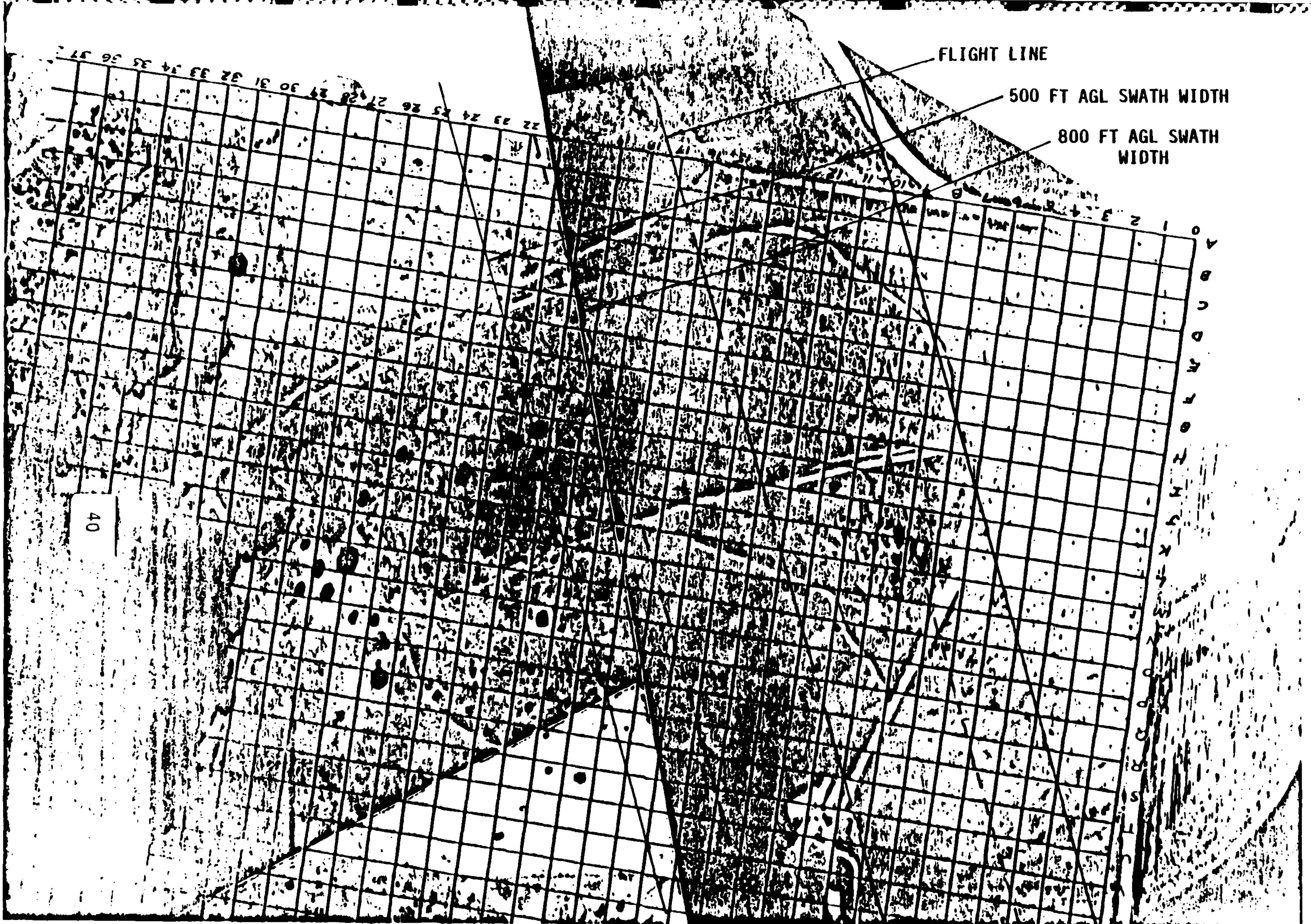


Figure 5. Infrared Scanner Coverage
100 foot squares

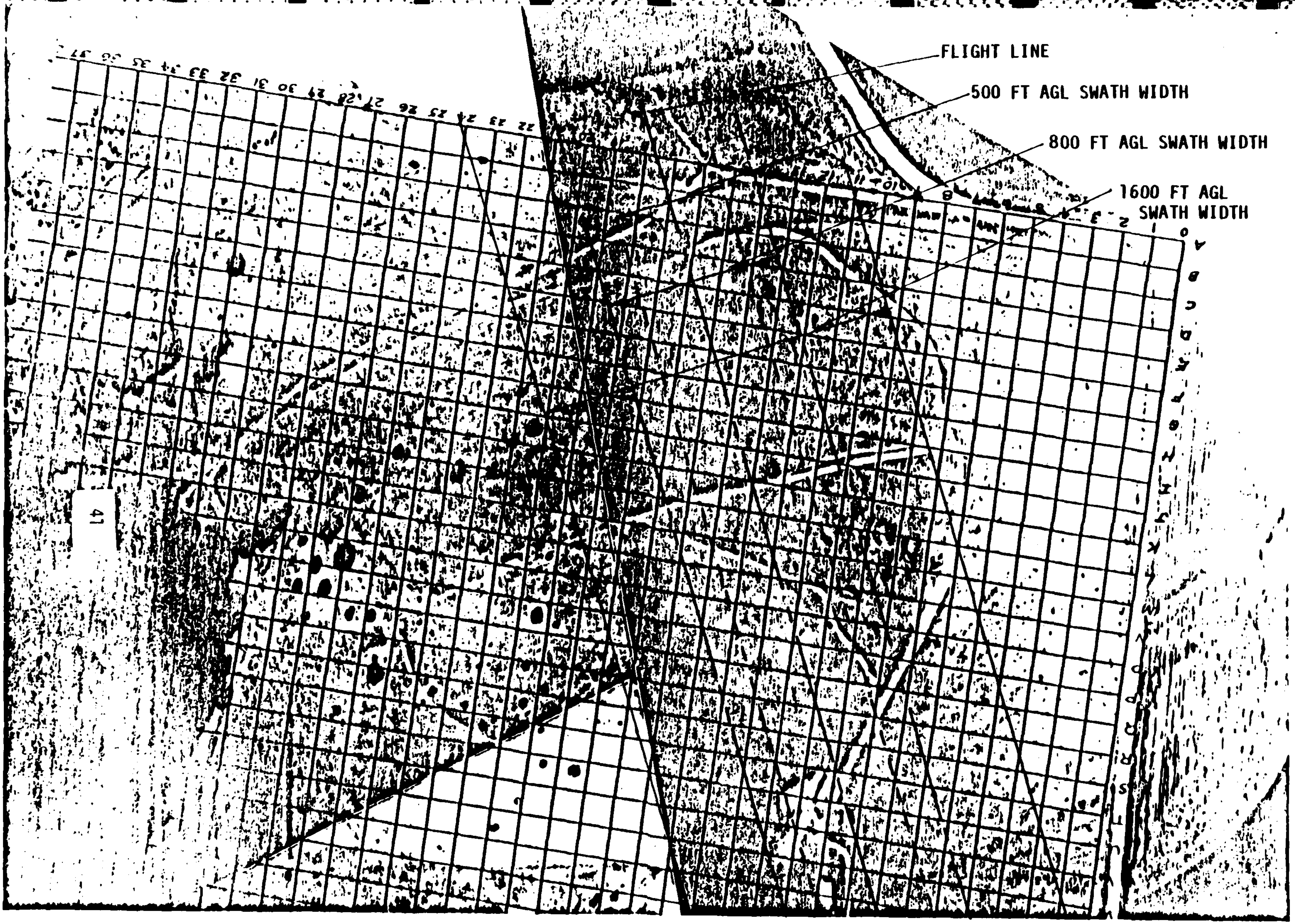


Figure 6. KA-76 Camera Coverage
6-Inch Focal Length
100 ft squares

APPENDIX B
SUPPLEMENT 1: DEFENSIVE MINEFIELD SIMULATION AT CAMP ADAIR

MERADCOM has requested that a large buried minefield be placed at Camp Adair to simulate a defensive minefield. Such minefields are characterized by their large size and by their presence for long time periods. How such minefields may be simulated at Camp Adair (or elsewhere) is the subject of this memorandum.

A heavy defensive minefield is characterized in Scenario 4 in the BDM report, BDM/W-79-231-TR, "System Definition for the Detection of Remote Minefields (U)," Volume I - UNCLASSIFIED. Five hundred and forty-five TM46 mines are installed in each minefield by three cargo trucks equipped with chutes. Each row is 50 meters apart and the mines are placed an average of every 5.5 meters. The mines are buried 2.5 cm deep and camouflaged to match surrounding ground. There will be 181 mines in each row so that the rows are 990 m long. The minefield depth is 100 m.

The Camp Adair area available for placing minefields (excluding the rifle ranges) is approximately one kilometer by 700 m. If an entire defensive minefield is to be simulated, the minefield must be oriented along the long side of the camp area or at a diagonal. In either case, the area available for moving the minefield arrays already in place is heavily restricted.

The fact that the sensors in the OV-1D Mohawk cannot cover the entire length of a defensive minefield unless flying along its length suggests that a shorter analog can be used. For the AN/AAS-24 scanner with its 80 degree scan field of view, the ground length scanned from 800 ft altitude is 409 m. This figure divided by 5.5 m yields 74 mines. At 500 ft altitude, the scan width is 256 m and the number of mines required is 47. Thus, 47 to 74 mines per row should be sufficient to simulate the buried minefield. In order to minimize

the minefield size and the number of mines required, it is recommended that the minefield be 330 m long (1/3 the full length) by 100 m wide. It is suggested that one row contain hand-buried mines and that the second and third rows consist of hand-dug holes but no mines.

A second simulated defensive minefield is proposed for the eastern edge of Camp Adair. No mines will be buried in this minefield. Three furrows will be plowed late in June when the mine layer is returned from Yakima. This simulated minefield also will be approximately 330 m long with 50 m spacing between furrows.

Space limitation is not a problem at Yakima. Defensive minefields at that locale can be located so that imagery of these minefields need not contain the smaller mine arrays. Two minefields, 500 m by 50 m similar to those at Camp Adair can be emplaced. One field will consist of hand-dug holes with 90 mines in one row and the other two rows empty. The second defensive minefield, the same size as the first, will consist of three furrows plowed with the mine layer. No mines will be buried in this minefield. This minefield will be put in place in June before the mine layer is returned to Camp Adair.

The number of mines suggested for burial at Camp Adair is 60. Currently, there are 12 M-15 mines in one row of a small buried array (Figure 1). By extending this row, only 48 mines are required. Twenty-nine M-15's will be shipped from ERIM and 11 M-15 mines from the Santiam airstrip will be diverted to Camp Adair. The remainder of the row can be filled when mines currently being used by G. Maksymonko, NVL become available. One hundred and fifty mines will be requested, eight for completing the defensive minefield row at Camp Adair, 90 for the minefield at Yakima and the remainder to recreate the small buried array at Camp Adair and for use at other sites.

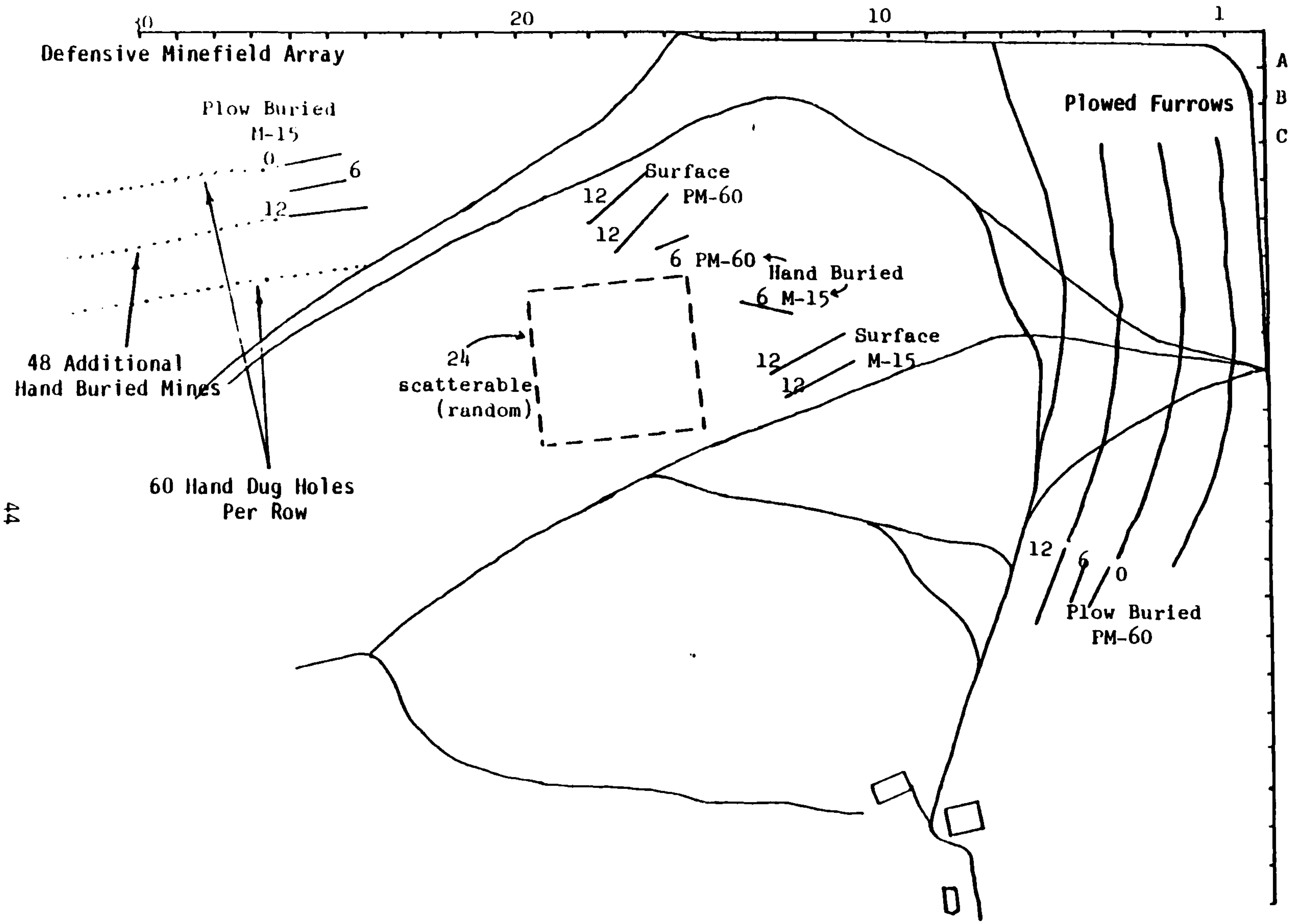


Figure 1. Defensive Minefield Array At Camp Adair Array II

APPENDIX C
SUPPLEMENT 2: SANTIAM AIRSTRIP

1.0 TEST PLAN OBJECTIVE

The objective of the tests to be performed at Santiam Pass is to provide data on the detectability of mines and minefields emplaced on snow. Several flights are to be made over the test site under conditions which are specified below. Both the AAS-24 scanner and the KA-76 camera are to be used on each pass over the minefield site. These tests supersede the tests at Mary's Peak.

Site Locations and Conditions

Santiam Junction Airstrip is located at the junction of US 20 and Oregon 22 (Figure 8), 87 miles by road and 67 miles by air from Corvallis. The airstrip is 2800 ft long in an east-west direction and at an altitude of 3760 ft. The strip is readily accessible from the highway.

Implementation

Array IIb will consist of a linear array located at the west end of the airstrip. The mines should be placed in an orderly pattern across the width of the airstrip. Snow depth should be on the order of two feet or less so that truck or other vehicle can be used to compact the snow and the compacted row spacings will be the width of the vehicle.

Two rows are required for 48 M-15's and two rows for the 48 PM-60's. One row will suffice for the 12 scatterable mines and one row for 8 each of the white-painted M-15b and PM-60's. The mines should be 4 to 5 meters apart in each row. One row of the M-15's and one row of the PM-60's should be on top of the compacted snow. The mines in the second row for each mine type should be covered to a depth of about two inches with loosely packed snow to simulate fresh snowfall.

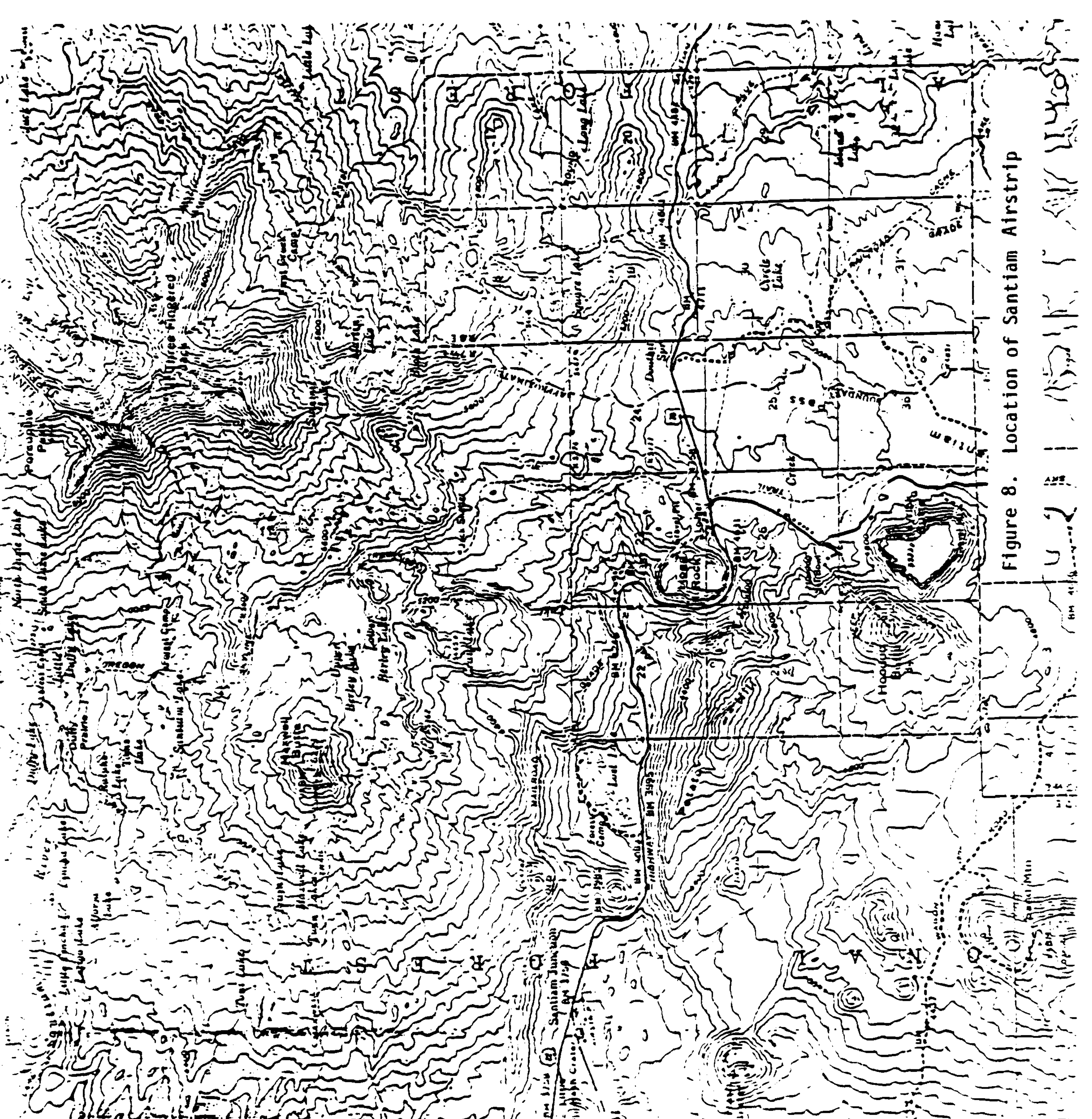


Figure 8. Location of Santiam Airstrip

Four of each type of white-painted mines should be placed on top of the compacted snow; the other four should be covered by two inches of loose snow.

Scatterable mines will undoubtedly create splash holes in snow because the mines possess high momentum. The nature of the splash will depend on the mine speed, angle of approach, mine attitude, mine rotational motions, and open snow depth and density. If the snow is not more than a few inches deep, a scatterable mine may expose a path on the ground. In deep snow, a mine may create a slanted hole and then burrow along the ground beneath the snow.

Since information on how scatterable mines land in snow is not available, test conditions will have to be assumed. Four mines should be placed in depressions in shallow snow (approximately 2 to 3 inches) with a ground exposure, ℓ, of 6 inches, 1.0 ft, 2.0 ft and 4.0 ft (Figure 9). Four other mines should be covered with 2 inches of loose snow. Four other mines should be covered with 2 inches of loose snow. Four others should be placed on top of the snow. All these mines can be placed in a single row parallel to the other rows. The scatterable mines should be spaced about 4 meters apart.

This array should be put in place by 0400 on the date of overflights. At least one foot of snow should be on the ground with no open ground observable. The mines should be left out for one 24-hour period. All mine positions should be marked with thin stakes (invisible in imagery) so that mine recovery is assured.

Three different mine field-snow configurations should be investigated. Data for a 24-hr period should be obtained as described above for the cases of: (1) mines on new snow, (2) mines off new snow (i.e., removed), and (3) mines under new snow (2 inches or less) (M-15's and PM-60's).

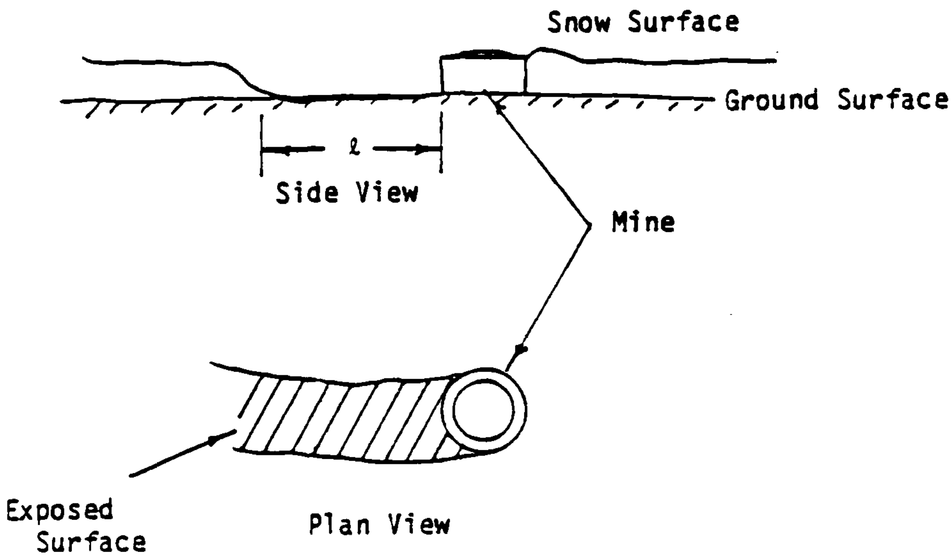


Figure 9. Simulated Scatterable Mine Landing in Shallow Snow

Procedure and Ground Truth

Hand-held radiometric measurements of 8-14 μm of each mine type and an adjacent snow background should be measured each hour from laydown until 2 hours after sunset and then every two hours. Wind speed and direction, as well as humidity and temperature, can be recorded at 10 to 15 minute intervals. A pyranometer should be used to measure solar input at the same intervals.

These measurements should be carried out for four different meteorologies: (1) 1 warm (32°-40°) bright sunny day, (2) 1 cold (15°-22°) bright day, (3) 1 warm (32°-40°) overcast all-day day, and (4) 1 overcast cold day (15°-22°). Full accurate data must be obtained, comments on moisture or frost on the mines must be noted. Special care should be exercised to include only the mine in the field of view of the radiometer. Initial radiometric measurements of the mines should be made just prior to placing them on the snow.

The photographic calibration aids (resolution and gray scale charts) should be emplaced near the mine arrays. It is expected that the best measure of aircraft altitude will be from photographs of the bar resolution chart.

Flights

All flights are to be made with primary concern given to flight safety. Passes should be made at altitudes of 500, 800, 1200, and 1600 ft. A pass over the Camp Adair compound area on each flight is required.

An east-west flight path flown in either direction is satisfactory although another flight path can be chosen if safety is not to be compromised. If possible, flights also should be made before the mines are laid out and after the mines are removed.

Barometric altitude should be recorded along with air temperature and humidity at the time of over-flight over the array. This information is needed to calculate altitude over the array. The radar

altimeter averages readings over a period of time and is not expected to yield sufficiently accurate altitude values over the array.

Previous flights over Camp Adair have been flown at 180 knots and this speed is satisfactory for flights over Santiam Pass. Higher speeds up to 225 knots can be used without detriment to the tests if safety precautions require.

Filter position No. 1, the open position, should be used on the AAS-24. The master gain switch should be on position 1 on the sunny days and on position 2 on the overcast days.

It is recommended that the 6-inch focal length lens be used with the KA-76 camera. The film should be EKC 2402 Plus-X Aerographic film.*

*GAF 2914, a Plus-X film whose characteristics are essentially the same as EKC 2402 may be used in place of the latter.

APPENDIX D
SUPPLEMENT 3: VISUAL OBSERVATION OF MINEFIELDS

The suggestion has been made by D. Griffith of ERIM that observers in scout helicopters may be able to detect the presence of mines and minefields. If such observations are possible, the advantages will be those of utilizing an existing asset and of shortening the communication chain. Scout helicopters are attached to brigades and can be assigned to use by maneuver battalions.

A preliminary test on an OH-58 or a VH-1 helicopter of the Oregon National Guard with flights over the Adair site is recommended. The test can be conducted under favorable weather conditions at a time between mid-morning and mid-afternoon.

It is estimated that a mine can be recognized under good contrast conditions at an altitude of 1 km. This estimate is based on the ability of an eye to distinguish objects at one minute of arc.

A key factor will undoubtedly be aircraft speed. As speed is increased, it is expected that the capability for detecting the presence of a minefield will decrease. The variation in this capability can be assessed through this preliminary test described below. It is noted that at any speed, the angular rate between observer and mines is lowest at the highest altitude. As altitude is decreased and the angular rate is increased, mines may become more difficult to see in spite of the fact that they subtend larger angles.

Observers should be shown images of the minefield so that they know what to look for. Familiarity with minefield disposition is another reason for flying initially in the hover mode.

The initial pass over the mine arrays should be performed at 1000 ft with the helicopter at or near hover. Depending upon whether or not the mines are discernible at this altitude, the altitude should be increased or decreased until the mines and furrows (buried mines)

are just discernible. Once the maximum altitude for a given observer has been determined, the aircraft speed should be increased by 25 knots. It is suggested that the initial pass at this speed be performed at half the maximum hover altitude and that passes be repeated at 25 knots at higher or lower altitudes until the mines are just discernible. The tests should be repeated at 25 knot increment increases in speed until mines are no longer discernible at any altitude or until the maximum cruisin speed of the helicopter is reached. Should the mines be undetectable even at 25 knots, helicopter speed should be reduced and the tests repeated until the mines are discernible.

APPENDIX E
SUPPLEMENT 4: YAKIMA FIRING CENTER

1.0 TEST PLAN OBJECTIVE

The objectives of the tests are to obtain data on the detectability of mines and minefields in a semi-arid region, to provide data suitable for assessing photointerpreter performance, to provide data useful in validating, revising and/or generating system component models and to provide inputs for the minefield detection data base.

2.0 SITE LOCATION AND FLIGHT PARTICIPANTS

The non-European environment test site is to be located at the Army's Yakima Firing Center in central Washington, 6 miles north of Yakima. This is a semi-arid region that is large enough to allow low level flights by RF-4C jet aircraft from the Idaho Air National Guard as well as Mohawk OV-1D flights by the Oregon National Guard.

Data collection is to be scheduled once a month for a period of 6 to 12 months with the initial flights scheduled for mid-June 1982. A special one-time collection (Black Knight Blitz) is planned for late April 1982.

Table 1 lists the locations of the several sites at the Yakima Firing Center. The Array III location is the heavily outlined rectangle on the map shown in Figure 1. Array IIIA site locations are indicated in Figure 2.

3.0 MINEFIELD IMPLEMENTATION

The mine arrays are to match closely the size of those at Array II: surface arrays of 36 PM-60's, 36 M-15's, and 15 scatterable; 18 plow-buried PM-60's and M-15's, and hand-buried arrays of 6 PM-60's and 6 M-15's. The Russian mine layer will be transported to Yakima for the first mission and stored on the base for use in deployment

TABLE 1
SITES AT YAKIMA, WASHINGTON

Array III				
	Minefield	085-903	7.7 miles north of Range Central and 4.5 miles east of I-82, Exit 11 Gate	
Array III (Operation Black Knight Blitz)				
No. 1	Minefield		135-695*	8 miles east of Range Central
No. 2	Calibration Site		076-697	4 miles east of Range Central
No. 3	Army Tank Barrier		052-733	2 miles north-east of Range Central

*UTM coordinates on Yakima Firing Center Map. 135 is 13 + 0.5 grid (100 m each) east of Reference and 695 is 69 + 0.5 grids north of Reference. [Grid 0 east is 120°23'35" west longitude and grid 70 north is 46°39'27" north latitude.]

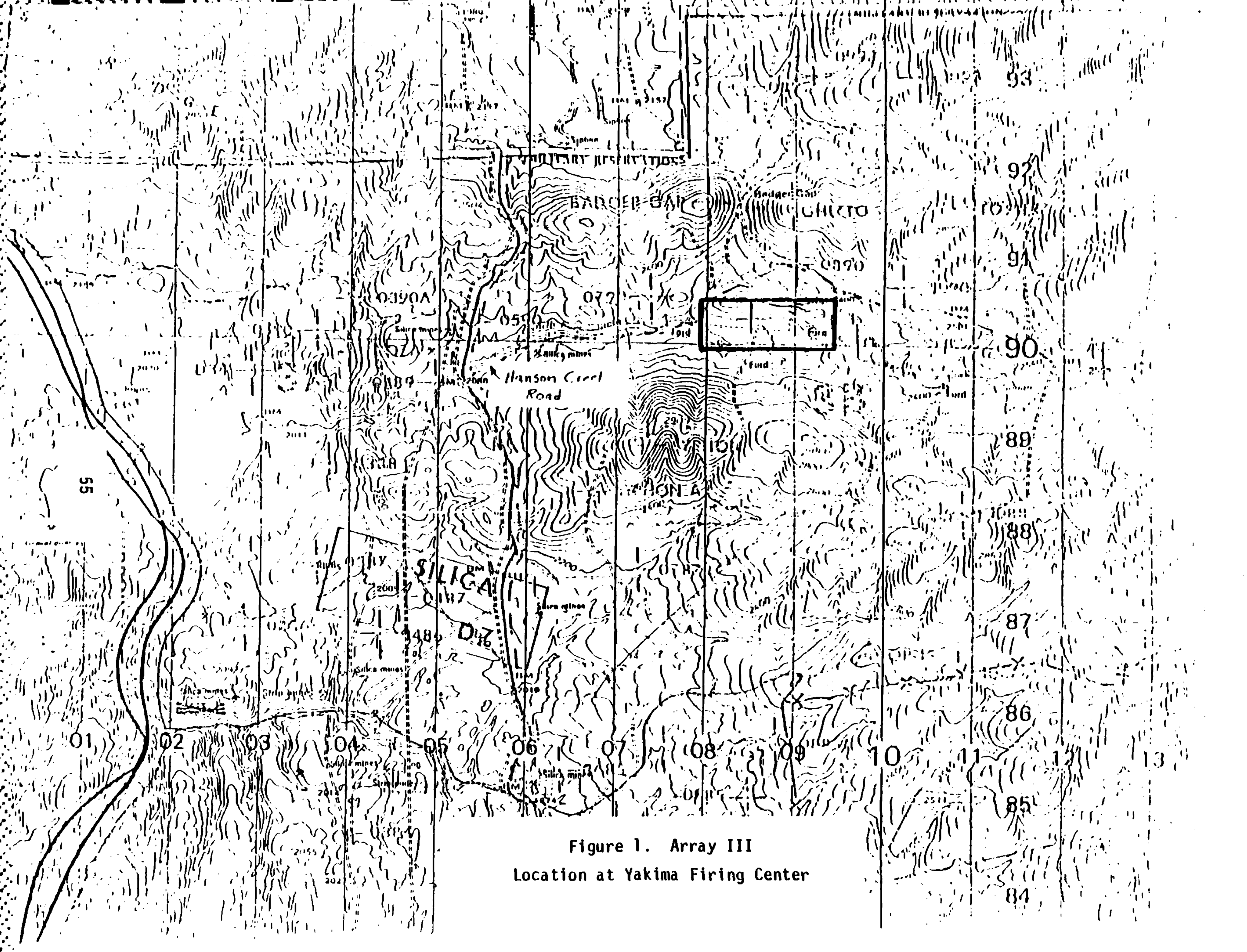
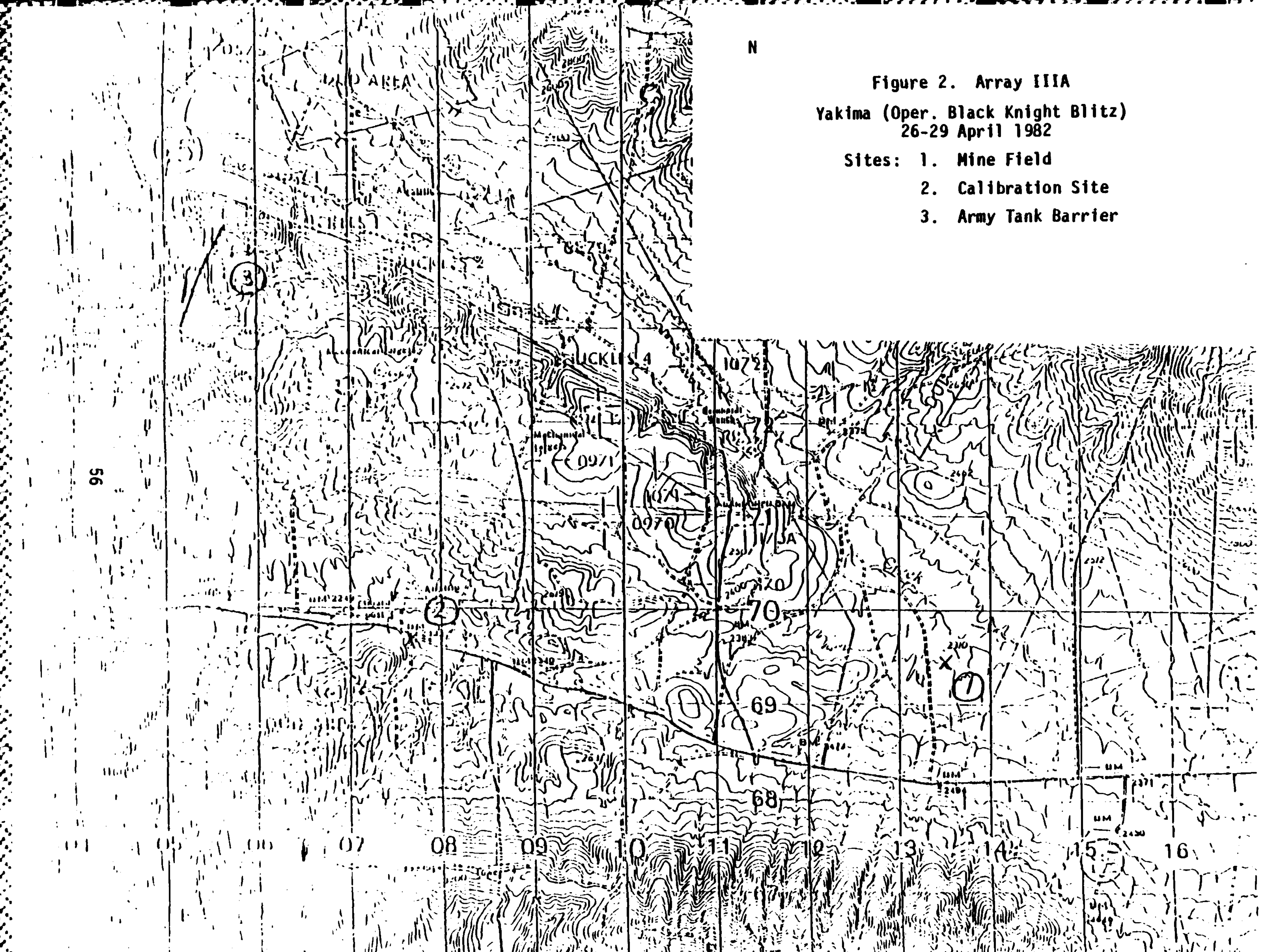


Figure 1. Array III
Location at Yakima Firing Center



N

Figure 2. Array IIIA

Yakima (Oper. Black Knight Blitz)
26-29 April 1982

Sites: 1. Mine Field
2. Calibration Site
3. Army Tank Barrier

of the main Array III mine field. Calibration aids are to be moved from Camp Adair to Yakima. The main weather station is to remain at Adair and newly purchased portable instruments for wind speed/wind direction (analog meters) and solar radiation (chart recorder) will be set up and read as needed. Ground level temperatures at the calibration site and at the mine field array will be measured with a radiometer and recorded on a drum recorder. Contact temperature of water pools, plates, mines and backgrounds will be recorded on cassette tape by the data logger.

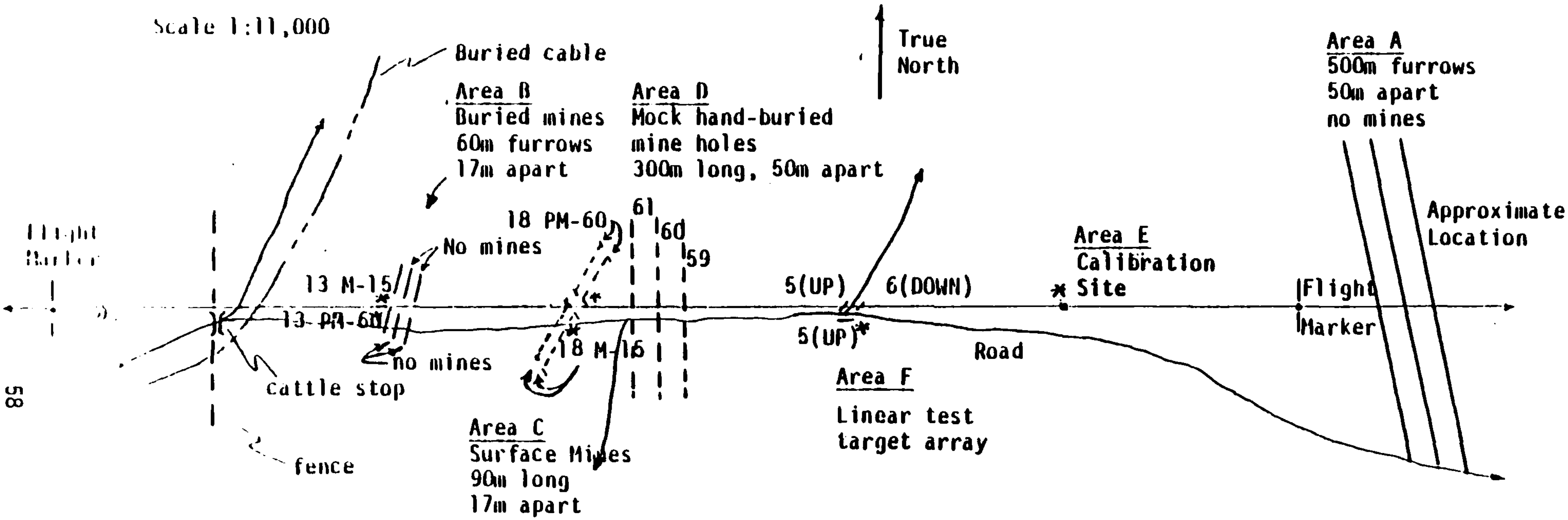
Two large defensive minefields are to be simulated. One field will consist of three plowed furrows, 500 m long, and spaced 50 m apart; no mines will be placed in the furrows. The second defensive minefield will consist of a row of 60 hand-buried and camouflaged mines and two rows of 60 hand-dug camouflaged holes. The minefield will be 300 m long and the rows will be 50 m apart. Minefield configuration is illustrated in Figure 3.

4.0 PLATFORMS AND SENSORS

Flights are to be made by the OV-1D Mohawks of the Oregon National Guard and the RF-4C's of the Idaho Air National Guard. The AN/AAS-24 scanner and the KA-76 camers are the sensors to be used by the Mohawks. The RF-4's are equipped with the AN/AAD-5 infrared scanner and the KS-87 vertical camera using a 6-inch focal length lens.

5.0 FLIGHTS

Mohawk flights are to be made at 500, 800 and 1200 ft altitudes. The IR scanner is to be used at the first two altitudes and the camera at the last two altitudes. If safety considerations permit, night missions as well as day missions will be flown.



*Radiometric measurements to be
taken in these areas

Figure 3. Site Plan for Array III, Yakima Firing Center, June 1982

The RF-4's are to be flown at 500, 1200 and 2500 ft during daytime missions and at 1000 and 2000 ft during nighttime missions. Both infrared scanner and cameras are to be used on all RF-4 missions.

The aircraft are to be flown west to east, essentially normal to the minefield rows. Markers are to be placed well in front of the minefields so that flight lines can be flown along the minefield centers and along lines deviated to the right and the left.

6.0 OPERATION BLACK KNIGHT BLITZ - ARRAY IIIA

During a visit to the site in March, ERIM learned of an Army exercise involving a large minefield and tank barrier to be constructed during the period 25-30 April 1982. Arrangements were made with Maj. Bill Frederics of the 1st Cavalry and Maj. Cake of the 15th Engineers from Ft. Lewis for ERIM to join with them in the exercise code named Operation Black Knight Blitz. Accordingly, locations were selected for the deployment of surface and plow-buried mine arrays and calibration arrays. These locations plus the Army's tank barrier are listed in Table 1, designated Array IIIA and the locations shown in Figure 2. Mine and calibration equipment dispositions are illustrated in Figures 4 and 5 respectively. Missions which were flown by Mohawks and RF-4C's are listed in Table 2.

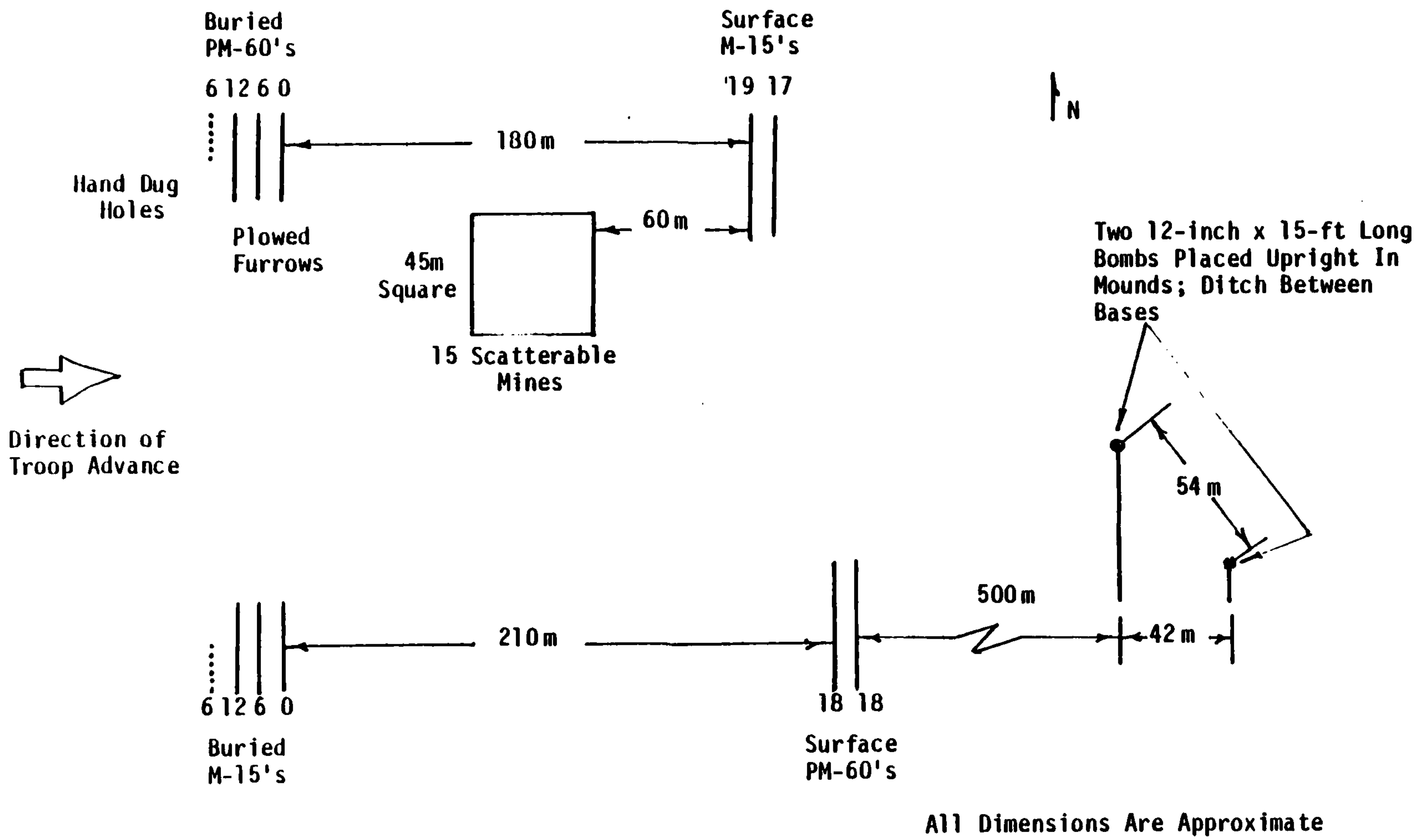
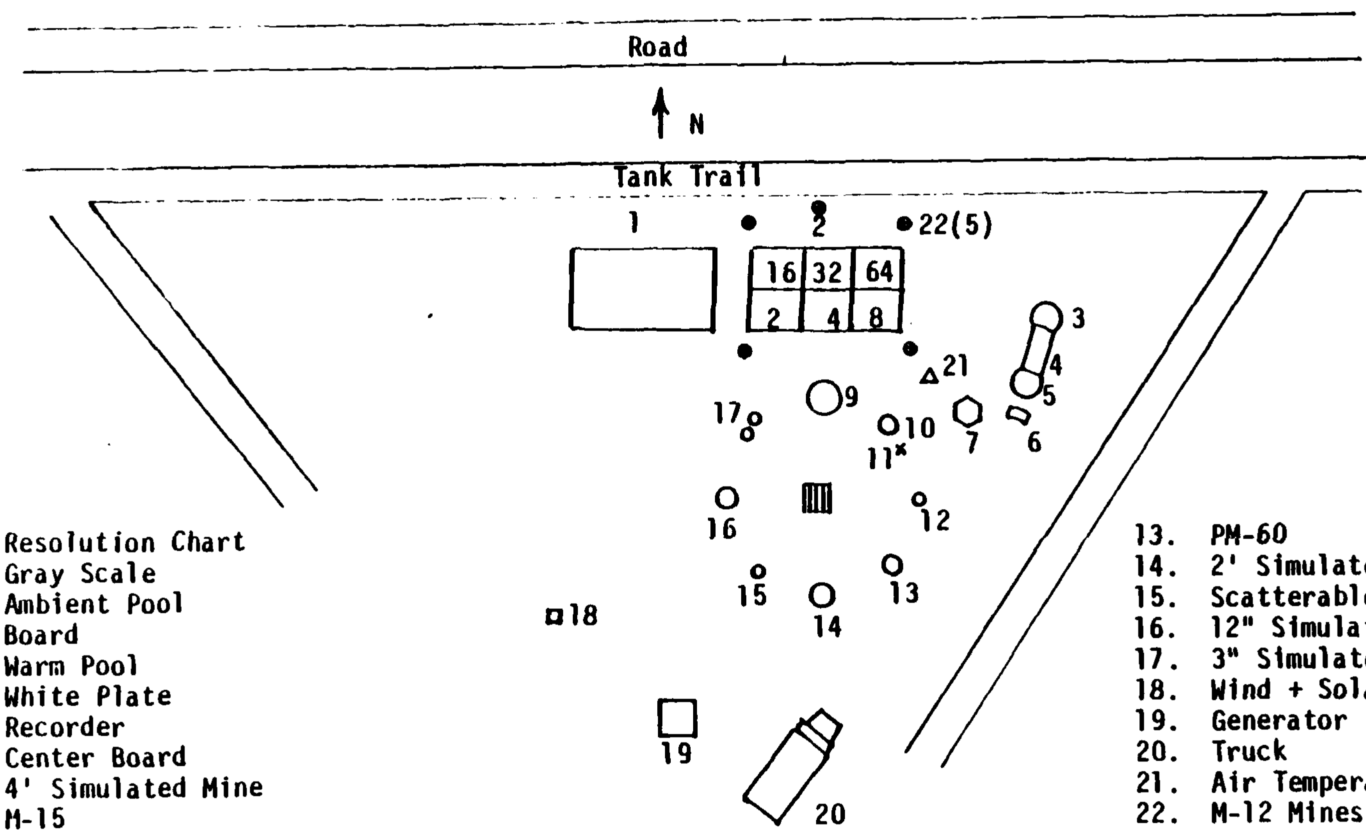


Figure 4. Array IIIA, Operation Black Knight Blitz, 26-29 April 1982, Yakima Firing Center



1. Resolution Chart
2. Gray Scale
3. Ambient Pool
4. Board
5. Warm Pool
6. White Plate
7. Recorder
8. Center Board
9. 4' Simulated Mine
10. M-15
11. Soil Probe
12. 6" Simulated Mine
13. PM-60
14. 2' Simulated Mine
15. Scatterable Mine
16. 12" Simulated Mine
17. 3" Simulated Mine
18. Wind + Solar
19. Generator (3.5 kw)
20. Truck
21. Air Temperature
22. M-12 Mines (Blue)

Figure 5. Calibration Site, Yakima Firing Center, Operation Black Knight Blitz, 26 - 29 April 1982

TABLE 2
BLACK KNIGHT BLITZ DATA COLLECTION AT ARRAY IIIA,
YAKIMA FIRING CENTER

Date	Time	Mohawk	RF-4C	Photo/Infrared Scanner
4/22/82*	1600		X	P + IR
4/26/82	1230	X		
4/27/82	1000, 1400, 2030	X X		P IR
4/28/82	1000, 1630		X	IR
4/28/82	1300 2030	X X		P IR
4/29/82	1000, 1530 2030	X X		P IR

*No mines present.

APPENDIX F
SUPPLEMENT 5: FILM/FILTER COMBINATION EXPERIMENT

Studies indicate that certain film/filter combinations should yield the highest detection probability of mines and minefields. The experiment described below is for the purpose of verifying the study findings.

In the visible range, panchromatic film, TRI-X or Plus X should be used in conjunction with a 47B (blue) filter. EKC 2402, a Plus-X aerographic black and white negative film is a suitable one.*

In the infrared range, an infrared aerographic film such as EKC 2424 should be used in conjunction with a 87C filter.

Currently, the Oregon National Guard does not have the 47B or the 87C filters.** These filters are also not available from Chicago Aerial Industries, the manufacturers of the KA-76 camera. These filters will be assembled from the program gelatins, optical glass and filter mounts, checked for spectral characteristics and furnished to the Oregon National Guard by ERIM.

The 6-inch focal length lens should be used with the KA-76 vertical framing camera.

Two aircraft should be flown along the same flight line, one after the other. One aircraft should use the EKC 2402 film with the 47B (blue) filter or the infrared red film with a 87C filter. The second aircraft should use the EKC 2402 film with a yellow filter (equivalent of a Wrattan 12) as has been flown to date to compare with the 47B images or IR 2424 with the Wratten 25A filter to compare with the 87C images. This procedure will allow photographs to

*GAF 2914, a Plus-X film whose characteristics are essentially the same as EKC 2402 may be used in place of the latter.

**Wratten 47 or Corning Glass 5-61 may be used in place of Wratten 47B and Wratten 87 or Schott Glass RG 780 may be used in place of Wratten 87C to decrease the filter factor.

be made under identical conditions but using different film/filter combinations. The effect of film/ filter combination on image quality can then be compared directly.

Flights are to be made under overcast conditions as well as in clear weather over Array II at Camp Adair. Priority should be given to the overcast weather condition flights. Flights should be made between 1000 to 1630 hours at altitudes of 800 feet and 1200 feet. Two passes at each altitude is suggested. Film and filter types used should be noted.

Films should be exposed to bring the target and background to a density of about 0.3 above gross fog. If there is any doubt, it is better to overexpose by one stop rather than underexpose. Development should be a gamma of about 1.

APPENDIX G
SUPPLEMENT G: ARRAY IIB, HYSLOP FARM

1.0 TEST PLAN OBJECTIVE

The objective of tests to be performed at the Oregon State Experimental Farms is to provide data on the detectability of mines and minefields emplaced among several types of agricultural crops. Flights are to be made over the test sites under conditions as specified below. Both the AAS-24 infrared scanner and the KA-76 camera are to be used on each pass over the minefield site if equipment availability permits.

2.0 SITE LOCATIONS

Hyslop Farms is located approximately 7 miles northeast of Corvallis, Oregon at the site labeled Oregon State University Test Field Laboratory in Figure 1. Schmidt Farm is located across the Lewisburg Road on the south and west of Hyslop Farm. East Farm is located about one mile east of Corvallis at the site marked Oregon State University Experimental Farm in Figure 2.

3.0 MINEFIELD IMPLEMENTATION

Mines are to be placed among five different crop types. These crops are barley, wheat, oats, sugar beets and potatoes. PM-60 and M-15 mines are to be placed among each type of crop. There are to be 12 surface and six buried mines of each type. Linear arrays are to be used with mines 4 to 5 meters apart.

When the mines are placed among a given crop depends on the growing season of each crop. Mines will be placed among oats, sugar beets, and potatoes in June.

Flights

All flights are to be made with primary concern given to flight safety. Passes are to be made at altitudes above ground level of

500, 800, 1200 and 1600 feet. The AAS-24 infrared scanner should be used at the 500 and 800 ft altitudes and the KA-76 at altitudes of 800, 1200 and 1600 feet.

Aircraft speed is to be 180 knots. At least one pass at 800 ft AGL should be made over the calibration array at Camp Adair whenever a mission is flown over the farm areas. Both the AN/AAS-24 and the KA-76 should be in operation.

Filter position No. 1, the open position should be used on the AAS-24. The master gain switch of the AAS-24 should be on position 1 on sunny days and position 2 on overcast days.

It is recommended that the 6-inch focal length lens be used with the KA-76 camera. The film should be EKC 2402 Plus-X Aerographic Film with a 47B (blue) filter.* The yellow filter should be used until the blue filter becomes available.

*GAF 2914, a Plus-X film whose characteristics are essentially the same as EKC 2402 may be used in place of the latter.

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